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American Fern Journal

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Edith Scamman (1882–1967)

ROLLA M. TRYON AND ALICE F. TRYON

"When the list in my pine-lot had reached sixteen, I climbed my neighbor's fences and wandered farther afield." This remark in Edith Scamman's (1923) delightful account of the ferns in her woods in Saco, Maine, sounded the prelude to long adventure and travel far afield in Alaska, Iceland, Europe, Costa Rica, Porto Rico and other Caribbean islands. Her botanical pursuits are most remarkable in that they followed studies in Middle English literature leading to a Master's degree from Radcliffe College and years of activity on church mission boards, both on the Prudential Committee, and as President of the Missionary Council of the Congregational Church Women of Maine.

Miss Scamman joined the American Fern Society in 1937 and served as its Secretary in 1950 and 1951. She was a member of the Overseers Committee to visit the Gray Herbarium, Harvard University, from 1942 to 1946 and held an appointment as Research Associate in the Gray Herbarium from 1949 to 1962; since that time she was an Honorary Research Associate. Her death on November 4, 1967, less than a month before her 85th birthday, was in Cambridge, Massachusetts, where she kept residence for many years.

Edith Scamman was born in Saco, Maine, on November 30, 1882, the only child of Francesca Allen Scamman and Henry Scamman; her grandfather, John Allen, was the attending physician. Her father, after years in California during the Gold Rush Period, returned to Maine and settled his family in the large home built by his grandfather. He instilled in his fond daughter a sense of adventure and pioneering spirit which were to carry her,

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decades later, to new frontiers. His death, when she was less than ten, brought her closer to her mother. They traveled to San Francisco, where she attended school for a short period. She entered Thornton Academy, in Saco, after returning to Maine.

EDITH SCAMMAN WITH PLANTS OF BLECHNUM BUCHTIENII NEAR LA CHONTA, IN THE SIERRA DE TALAMANCA OF COSTA RICA, IN APRIL 1951.

Except for her college years and a brief time in New York she lived with and devotedly cared for her mother. She graduated from Wellesley College in 1907 with a major in English. Two years later she received a Master's degree from Radcliffe College, and her study in Middle English, "The Alliterative Poem: Death and Life," was published in 1910, in Radcliffe College Monographs, Studies in English and Comparative Literature.

Her botanical activities centered at the Gray Herbarium, Harvard University, when she came there in 1935 to study with Professor M. L. Fernald and enrolled in his classes as a Radcliffe student. She became acquainted with many students and eminent botanists who were to influence her work. Professor Fernald at that time was interested in plant distributions in unglaciated Alaska; Miss Scamman became a willing ally and promptly embarked on a program of botanical exploration in this region. She collected there on nine separate trips (the last in 1954) and she made a total of some 5000 collections which are deposited at Harvard. Her research on these collections was published in 1940, "A list of plants from interior Alaska." Many of her specimens were sent to specialists and several new species, a Spring Beauty (*Claytonia scammaniana*), a Poppy (*Papaver scammaniana*) and a Crucifer (*Lesquerella arctica* var. *scammanae*), were named for her. She published an account of the ferns of the Yukon in THIS JOURNAL in 1949.

During this period she was also closely associated with Mr. C. A. Weatherby. With his encouragement and guidance she enlarged her botanical experience during the preparation of "The Ferns and Fern Allies of New Hampshire." This useful reference for students and botanists interested in New England ferns was published by the New Hampshire Academy of Science in 1947. It is an accurate and well written account with many illustrations. Her deep appreciation of botanical specimens is revealed in the introductory remark: "As one studies the beautiful specimens gathered and preserved with so much care and reads the handwriting of many old labels of former years one can picture the delight and sense of achievement which came to many early fern students."

With her interests concentrated on the ferns, she embarked in a wholly new direction, in tropical America with the study of Costa Rican ferns. She collected there in 1951, 1953, 1955 and 1956. During these trips she made about 1400 collections representing about 500 species. Specimens of these are also deposited at the Gray Herbarium. The extensive collections thus accumulated formed the basis of several publications, with technical keys, illustrations, and descriptive material. The first of these was on the Maidenhair ferns (*Adiantum*) of Costa Rica, in 1960. Although she was at this time in her 78th year, she continued with similar treatments of other genera: *Pteris*, *Oleandra*, and *Eriosorus*. A paper on the genus *Asplenium* was in preparation at the time of her death. Her collections from Costa Rica as well as those from the Caribbean area have been cited in other recent studies, and a rare fern from the high mountains of Costa Rica, *Jamesonia scammanae*, commemorates her studies and collections in the American tropics.

Her appreciation and concern for the American Fern Society, as a member for thirty years and as its Secretary, is thoughtfully expressed by her bequest of three thousand dollars to the Society.

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A Study of Spore Characteristics of the Ferns of Indiana

JEANETTE C. OLIVER

Most taxonomic work on the ferns in the past has involved gross morphology, stelar anatomy, and the structure and position of the sori. Recently attention has been directed toward the diagnostic values of spore characteristics (Brown, 1960; Crane, 1953; McVaugh, 1935; and Marengo, 1956).

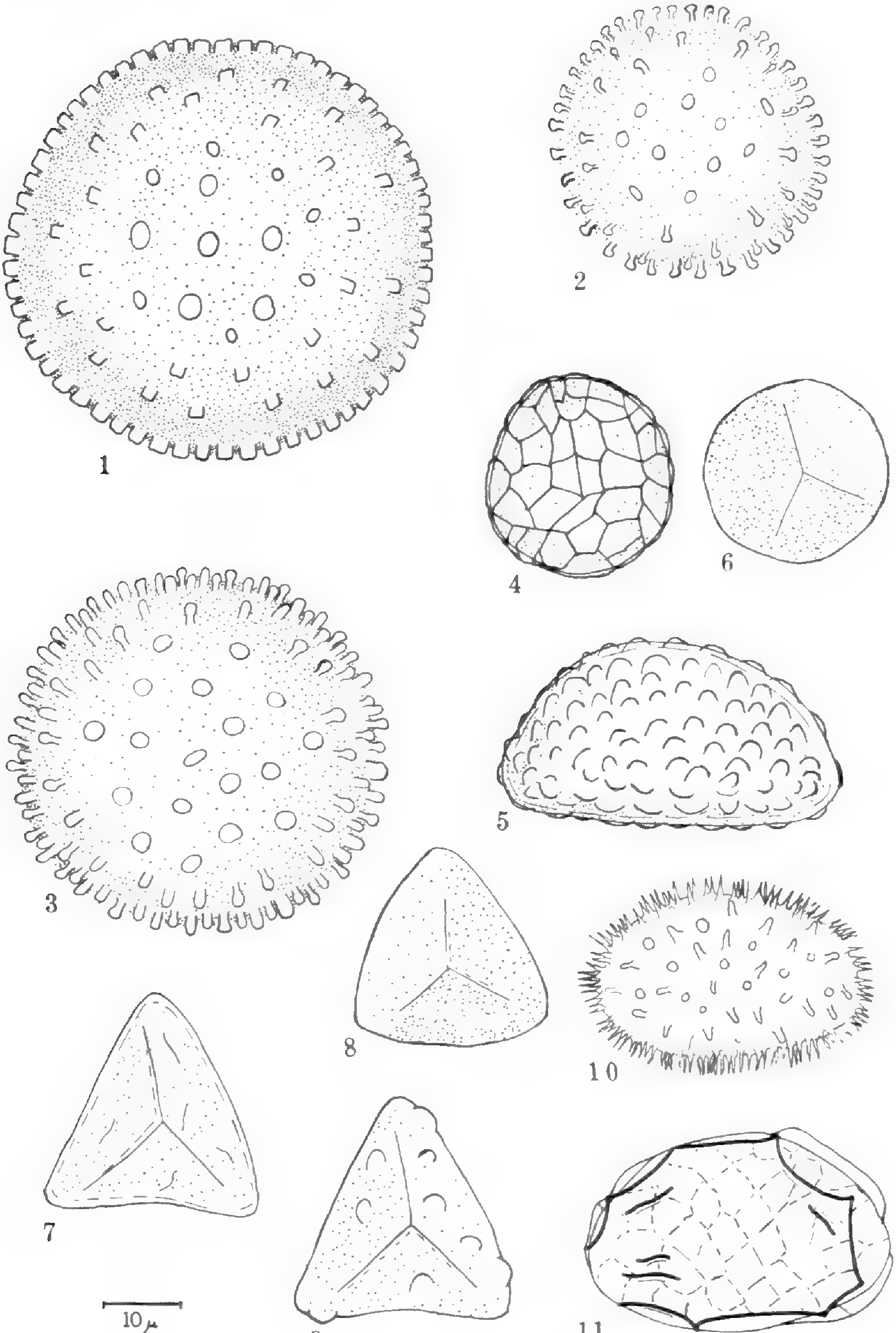
My work has been carried out to assess the value of spores as a means of identification of the ferns indigenous to Indiana. As a result a diagnostic key was devised using spore characteristics. The spores examined were fresh, except for *Dennstaedtia punctilobula* (Michx.) Moore, *Woodwardia virginica* (L.) J. E. Smith, *Pellaea atropurpurea* (L.) Link, and *Cheilanthes lanosa* (Michx.) D. C. Eaton, which were obtained from herbarium specimens. These four ferns have been collected in Indiana, but are rare (Deam, 1940).

Untreated spores were observed for color and size. Fifty spores of each species were measured using an ocular micrometer. Spores of each species were taken from several specimens chosen randomly. For detailed study, spores were treated according to the acetolysis procedure of Erdtman (1943).

A set of reference slides was prepared by mounting spores in Hoyer's Medium. This clears the spores and acts as a preservative. Slides may be kept for several years.

Most species can be distinguished by differences in shape and in the structure and markings of the perispore and exospore layers. However, the species of *Botrychium* and *Osmunda* are very similar, with the main difference being size.

The spores of *Athyrium pycnocarpon* (Spreng.) Tidestr. closely resemble those of *Asplenium*. Further, the spores of *Athyrium asplenioides* (Michx.) Desv. have ridges much like *A. pycnocarpon*, whereas *Athyrium angustum* (Willd.) Presl. does not have distinct wings and ridges, but is tuberculate.



DRAWINGS OF SPORES OF INDIANA FERNS

The species of *Thelypteris* are placed in the genus *Dryopteris* by some authors. On the basis of spore morphology, it is difficult to distinguish characteristics which are confined to either of the genera. *Thelypteris hexagonoptera* (Michx.) Weath., *T. phegopteris* (L.) Slosson, and *T. noveboracensis* (L.) Nieuwl. are distinct in that there are no obvious perispore wings. *Thelypteris palustris* Schott has perispore wings similar to *Dryopteris*. The gross, roughened spores of *T. palustris*, however, are similar to other members of the genus. Some authors place *T. hexagonoptera* and *T. phegopteris* in a different genus, *Phegopteris*, but spore morphology does not support this concept.

Key to the Genera and Species

1\. Perispore (perinium) absent or obscure 2
1\. Perispore present 15

2\. Spores clear or nearly so 3
2\. Spores yellow or brown 10

3\. Spores globular 4
3\. Spores otherwise 7

4\. Protoplast green; exine piliferous 5
4\. Protoplast not green; exine reticulate. *Ophioglossum engelmannii* Prantl (30–40 μ; *Fig. 4*)

5\. Spores less than 60 μ in diameter 6
5\. Spores 60—69 μ in diameter . . . . . *Osmunda regalis* L. (*Fig. 1*)

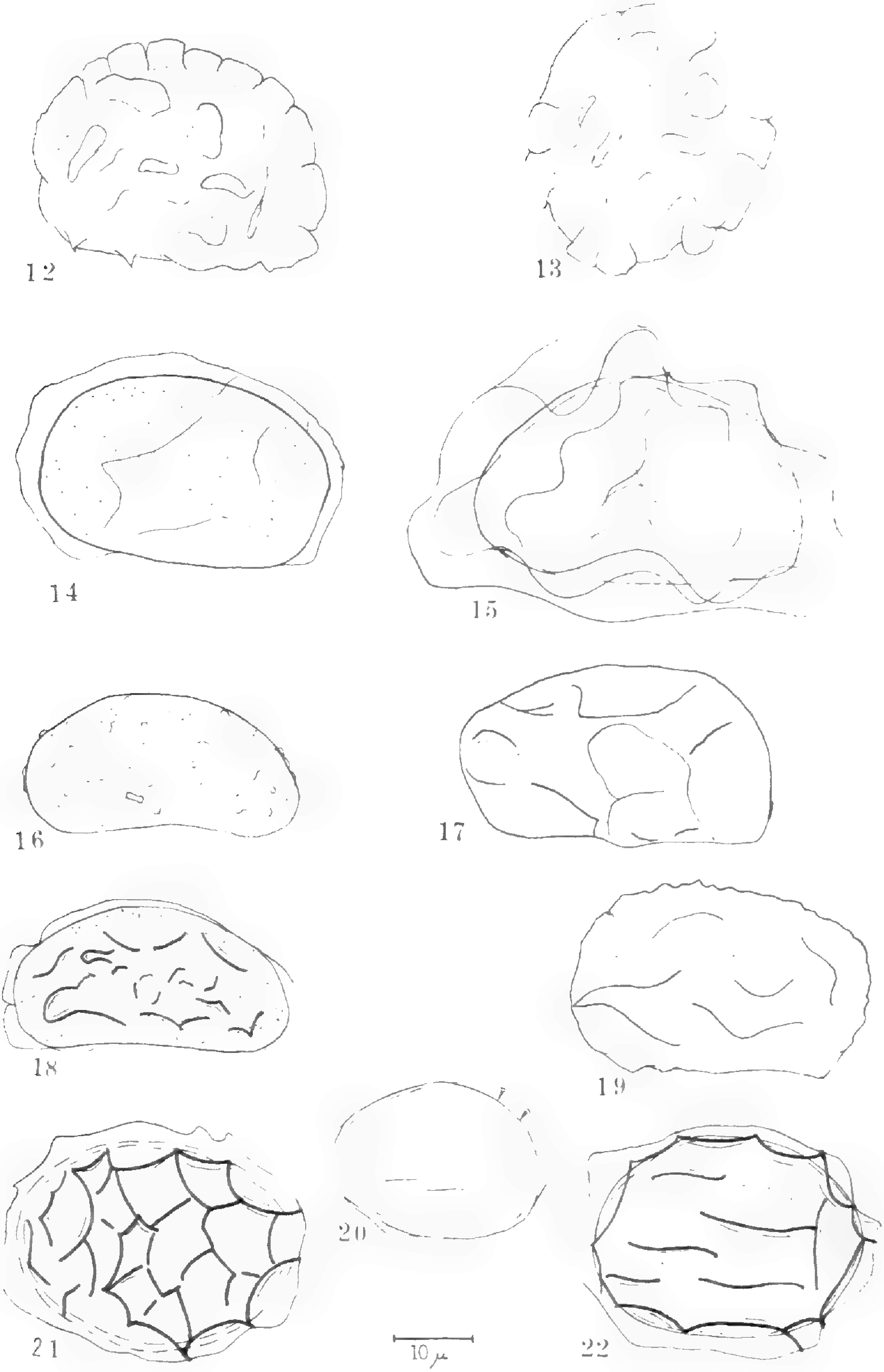
6\. Spores 36—45 μ in diameter . . . . . *Osmunda claytoniana* L. (*Fig. 2*)
6\. Spores 46—58 μ in diameter . . . . . *Osmunda cinnamomea* L. (*Fig. 3*)

7\. Spores tetrahedral 8
7\. Spores bilateral . . . . . *Polypodium vulgare* L. (38–45 × 53–60 μ; *Fig. 5*)

8\. Exine tuberculate 9
8\. Exine smooth . . . . . *Adiantum pedatum* L. (32–41 μ; *Fig. 7*)

9\. Spores 42–44 × 38–40 μ . . . . . *Botrychium dissectum* Spreng.
9\. Spores 35–36 × 35–36 μ . . . . . *Botrychium virginianum* (L.) Swartz (*Fig. 6*)

Fig. 1. Osmunda regalis L. Fig. 2. Osmunda claytoniana L. Fig. 3. Osmunda cinnamomea L. Fig. 4. Ophioglossum engelmannii Prantl. Fig. 5. Polypodium vulgare L. Fig. 6. Botrychium virginianum (L.) Swartz. Fig. 7. Adiantum pedatum L. Fig. 8. Pteridium aquilinum (L.) Kuhn. Fig. 9. Dennstaedtia punctilobula (Michx.) Moore. Fig. 10. Cystopteris fragilis (L.) Bernh. Fig. 11. Cystopteris bulbifera (L.) Bernh.



DRAWINGS OF SPORES OF INDIANA FERNS

10. Spores tetrahedral 11
10. Spores bilateral or oval 12

11. Exospore minutely scaly.
Pteridium aquilinum (L.) Kuhn (28–34.5 μ; *Fig. 8*)
11. Exospore verrucose.
Dennstaedtia punctilobula (Michx.) Moore (30–35 × 20–25 μ; *Fig. 9*)

12. Spores bilateral, often spinulose 13
12. Spores round or oval, scaly 14

13. Spores spinulose.
Cystopteris fragilis (L.) Bernh. (23–32 × 34–41 μ; *Fig. 10*)
13. Spores granular with a few prominent ridges.
Cystopteris bulbifera (L.) Bernh. (17–26 × 34–38 μ; *Fig. 11*)

14. Spores oval, yellow-brown.
Pellaea atropurpurea (L.) Link (43–46 × 53–56 μ; *Fig. 12*)
14. Spores round, yellow.
Cheilanthes lanosa (Michx.) D. C. Eaton (38–42 μ; *Fig. 13*

15. Perispore closely adherent 16
15. Perispore loosely attached.
Woodwardia virginica (L.) J. E. Smith (36–40 × 42–60 μ; *Fig. 14*)

16. Spores yellow to brown 17
16. Spores clear to grayish.
Polystichum acrostichoides (Michx.) Schott (35–45 × 48–53 μ; *Fig. 15*)

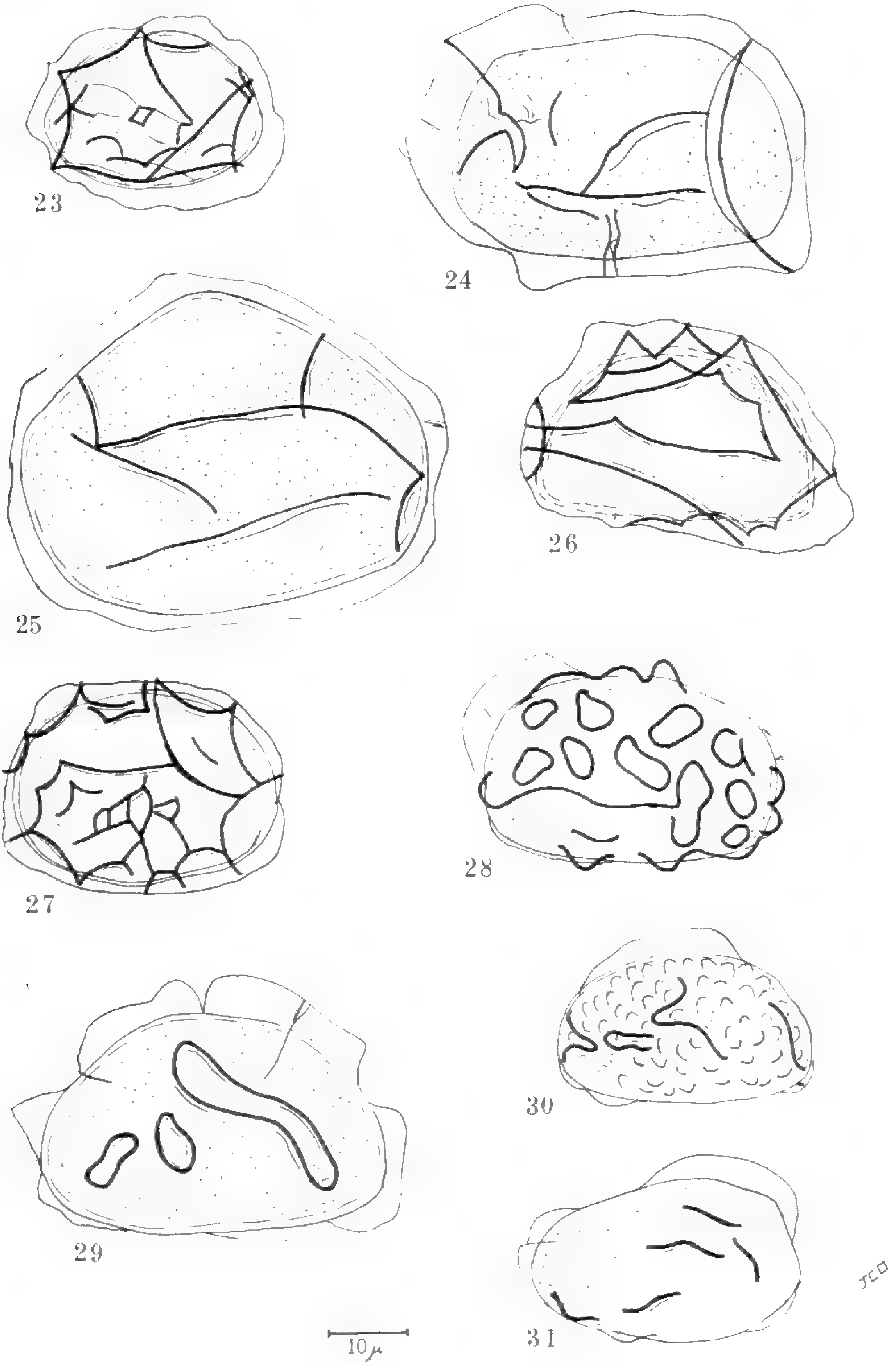
17. Perispore wing not obvious 18
17. Perispore wing distinct 24

18. Exine with subtle, reticulate or oval ridges 19
18. Exine tuberculate, often with ridges 22

19. Ridges elongate, distinct; spore surface granular or smooth 20
19. Ridges limited, inconspicuous; spore surface granular.
Thelypteris phegopteris (L.) Slosson (20–47 × 30–60 μ; *Fig. 16*)

20. Ridges broken; spore surface granular 21
20 Ridges anastomosing, reticulate; spore surface smooth.
Thelypteris hexagonoptera (Michx.) Weath. (20–27 × 39–50 μ; *Fig. 17*)

Fig. 12. Pellaea atropurpurea (L.) Link. Fig. 13. Cheilanthes lanosa (Michx.) D. C. Eaton. Fig. 14. Woodwardia virginica (L.) J. E. Smith. Fig. 15. Polystichum acrostichoides (Michx.) Schott. Fig. 16. Thelypteris phegopteris (L.) Slosson. Fig. 17. Thelypteris hexagonaptera (Michx.) Weatherby. Fig. 18. Thelypteris palustris Schott. Fig. 19. Thelypteris noveboracensis (L.) Nieuwl. Fig. 20. Athyrium angustum (Willd.) Presl. Fig. 21. Athyrium pycnocarpon (Spreng.) Tidest. Fig. 22. Athyrium asplenioides (Michx.) Desv.



DRAWINGS OF SPORES OF INDIANA FERNS

21. Wings distinct. . . .*Thelypteris palustris* Schott (34–45 × 53–63 μ; *Fig. 18*)
21. Wings absent.
Thelypteris noveboracensis (L.) Nieuwl. (26–34 × 34–45 μ; *Fig. 19*)

22. Wings distinct; spore surface ridged. 23
22. Wings obscure; spore surface tuberculate.
Athyrium angustum (Willd.) Presl (27–38 × 32–39 μ; *Fig. 20*)

23. Ridges reticulate, anastomosing.
Athyrium pycnocarpon (Spreng.) Tidestr. (32–41 × 38–49 μ; *Fig. 21*)
23. Ridges elongate, little anastomosing.
Athyrium asplenioides (Michx.) Desv. (33–35 × 39–42 μ; *Fig. 22*)

24. Perispore wing wide or continuous. 25
24. Perispore wing narrow or broken. 26

25. Ridges prominent, primarily longitudinal.
Camptosorus rhizophyllus (L.) Link (24–32 × 34–39 μ; *Fig. 23*)
25. Ridges few, both longitudinal and transverse.
Woodsia obtusa (Spreng.) Torr. (30–34 × 38–48 μ; *Fig. 24*)

26. Perispore wing wide, broken. 27
26. Perispore wing narrow, broken or not.
Onoclea sensibilis L. (36–57 × 58–65 μ; *Fig. 25*)

27. Ridges regularly anastomosing, the pattern reticulate. 28
27. Ridges occasionally anastomosing, mostly not reticulate. 29

28. Major ridges 3–4 in lateral view; spore surface granular between ridges.
Asplenium pinnatifidum Nutt. (30–38 × 41–53 μ; *Fig. 26*)
28. Major ridges many; spore surface not granular between ridges.
Asplenium platyneuron (L.) Oakes (32–41 × 38–52 μ; *Fig. 27*)

29. Ridges closed, anastomosing. 30
29. Ridges elongate, little anastomosing. 31

30. Spores entirely ridged.
Dryopteris marginalis (L.) Gray (26–38 × 38–53 μ; *Fig. 28*)
30. Spores sparsely ridged.
Dryopteris cristata (L.) Gray (30–40 × 40–60 μ; *Fig. 29*)

31. Ridges loosely reticulate.
Dryopteris spinulosa (Muell.) Watt (26–35 × 38–45 μ; *Fig. 30*)
31. Ridges elongate, not reticulate.
Dryopteris goldiana (Hook.) Gray (25–30 × 30–40 μ; *Fig. 31*)

Fig. 23. Camptosorus rhizophyllus (L.) Link. Fig. 24. Woodsia obtusa (Spreng.) Torr. Fig. 25. Onoclea sensibilis L. Fig. 26. Asplenium pinnatifidum Nutt. Fig. 27. Asplenium platyneuron (L.) Oakes. Fig. 28. Dryopteris marginalis (L.) Gray. Fig. 29. Dryopteris cristata (L.) Gray. Fig. 30. Dryopteris spinulosa (Muell.) Watt. Fig. 31. Dryopteris goldiana (Hook.) Gray.

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Rate of Gametophyte Maturation in Sexual and Apogamous Forms of Pellaea glabella

DEAN P. WHITTIER[1]

Wagner et al (1965) have reported the occurrence of a diploid sexual form of *Pellaea glabella* var. *glabella* in Missouri. Previously, this variety was known only to be obligately apogamous at the $4x$ chromosome level (Tryon and Britton, 1958). A comparison of the haploid and tetraploid gametophytes of the sexual and apogamous forms respectively is of interest because artificially produced polyploid series of gametophytes in other fern genera (Manton, 1950; Whittier, 1966) demonstrate a number of quantitative variations. The sexual and asexual methods of sporophyte formation have different requirements, e.g., water for sperm movement, which is required for sexual reproduction, is un-

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[1] I wish to acknowledge Prof. W. H. Wagner, Jr. for suggesting the study of this species and Mr. D. R. Farrar for his assistance in locating the plants at DeSoto, Missouri. This study was supported in part by the Vanderbilt University Research Council.

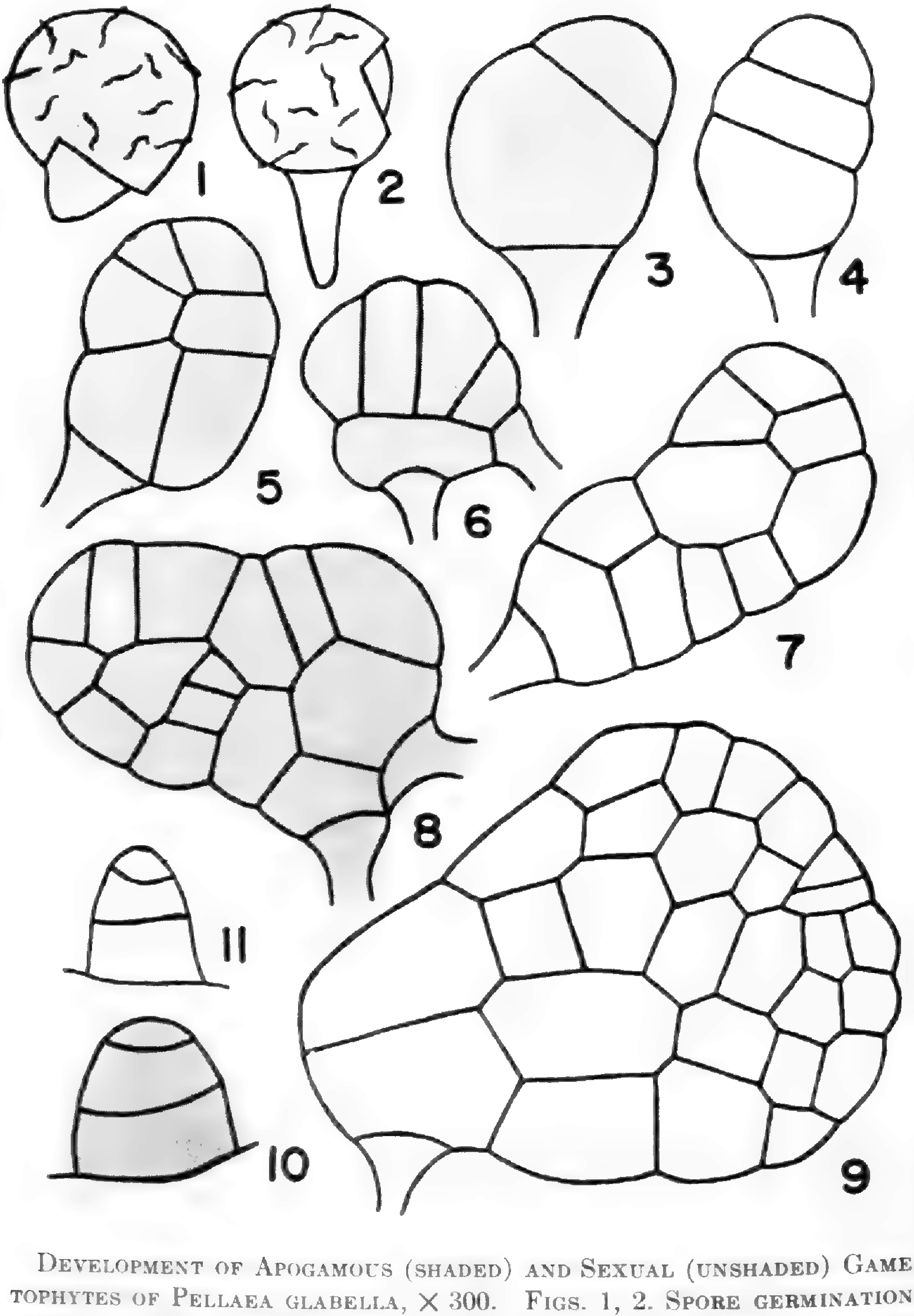
necessary for apogamy. Modifications in gametophyte growth and development possibly accompany the method of sporophyte formation. The gametophytes of the sexual and apogamous forms of *P. glabella* var. *glabella* provide an opportunity to investigate prothalli of the same species with variations in chromosome number and mode of sporophyte formation.

Spores of the sexual (*Whittier 3*) and apogamous (*Whittier 10*) forms of *Pellaea glabella* var. *glabella* were obtained from DeSoto, Missouri (See Wagner *et al*, 1965) and Rome, Tennessee, respectively. Voucher specimens have been deposited in the Vanderbilt University Herbarium. Aseptic techniques (Whittier, 1964) were employed to sterilize and sow the spores on 25 ml of nutrient medium in petri plates. The medium consisted of Knudson's solution of mineral salts, FeEDTA, minor elements, 1% or 0% sucrose, 0.6% agar, and had a pH of 6.0 (Whittier, 1964). In one experiment, antheridial hormone (Näf, 1958) at a 1/10 dilution was incorporated into the medium to insure antheridium formation.

The areas of the gametophytes were determined with a polar planimeter (Whittier, 1964). The measurements reported are the means of 64 individuals, and the standard errors of the means are included. Over 200 gametophytes were examined to determine the percent with archegonia or initial stages of apogamy.

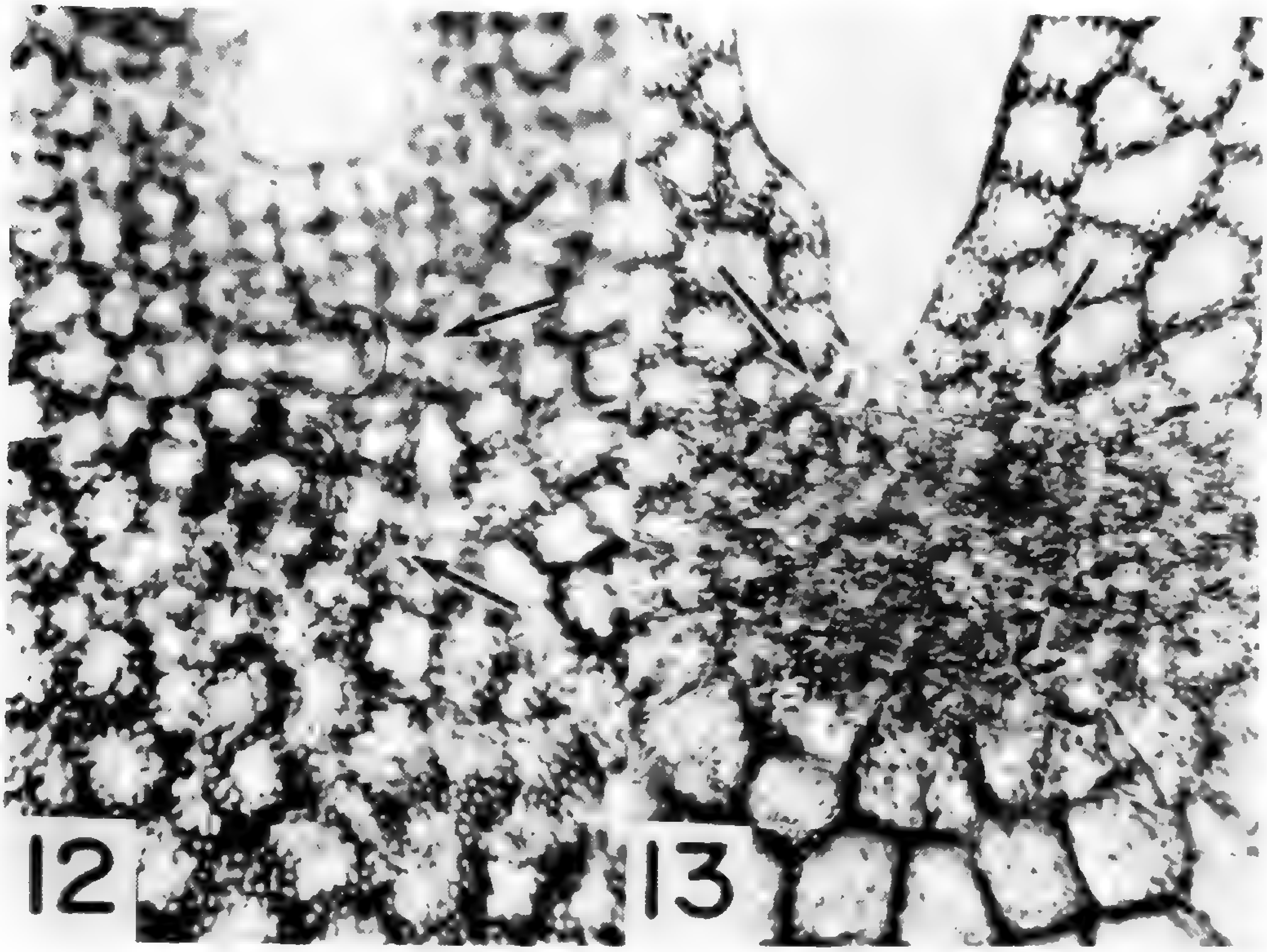
Spores of the apogamous and sexual forms are trilete with low ridges on the exine. Spores of the apogamous form exceed in diameter (73.2 ± 0.6μ) those of the sexual form (55.7 ± 0.5 μ).

The development of the gametophytes was observed using prothalli grown on the nutrient medium lacking sucrose. The early development in both forms is very similar. The spores become swollen and crack at the triradiate ridge in three days for the apogamous form and in four days for the sexual form. The spore divides to produce the first prothallial cell and first rhizoid which enlarge to rupture the spore coat (*Figs. 1, 2*). Generally, two or three cell divisions give rise to a filament of three to four cells (*Figs. 3, 4*). A small plate of cells arises as the cells divide parallel to the filament axis (*Fig. 5*). In some instances no filament is formed, as irregular cell divisions of the first prothallial cell form



Development of Apogamous (shaded) and Sexual (unshaded) Gametophytes of Pellaea glabella, × 300. Figs. 1, 2. Spore germination. Figs. 3, 4. Early filamentous stage. Figs. 5–8. Young plate stages. Fig. 9. Plate stage with apical cell. Figs. 10, 11. Antheridia.

a plate of cells directly (*Fig. 6*). With additional cell divisions and growth, larger plates develop (*Figs. 7, 8*) and ultimately an apical cell arises (*Fig. 9*). The plate continues to grow by the activity of the apical cell, but eventually a marginal meristem replaces the apical cell (*Fig. 12*) and a small cordate prothallus develops.



APICAL NOTCH REGION OF MATURE CORDATE GAMETOPHYTES, × 200. FIG. 12. SEXUAL FORM SHOWING MARGINAL MERISTEM AND ARCHEGONIA (ARROWS). FIG. 13. APOGAMOUS FORM SHOWING EARLY APOGAMOUS DEVELOPMENT WITH SPOROPHYTIC HAIRS (ARROWS).

In the presence of antheridial hormone, the young gametophytes form antheridia (*Figs. 10, 11*). The diameter of the antheridia are $48.6 \pm 0.4\,\mu$ and $36.2 \pm 0.3\,\mu$ for the apogamous and sexual forms respectively. No antheridia were observed unless antheridial hormone was added to the medium.

After the initiation of the small cordate prothallus, the development of the gametophytes differ. In the prothallus of the apogamous form, cells behind the notch divide to produce a mass of meristematic cells (*Fig. 13*) which develop into an apogamous sporophyte. The cells behind the notch in the sexual form give rise to a cushion with archegonia (*Fig. 12*). The archegonia and antheridia of the sexual form are functional because diploid juvenile sporophytes have been collected at DeSoto. Fertilization was not accomplished in culture, apparently due to technical difficulties.

Table I. Size Comparison (in mm²) of Sexual and Apogamous Gametophytes of Pellaea glabella

	Sexual form		*Apogamous form*	
	0% sucrose	*1% sucrose*	*0% sucrose*	*1% sucrose*
Size on 21st day	0.20 ± 0.01	0.28 ± 0.01	0.39 ± 0.02	0.52 ± 0.02
Size at first apogamy or archegonia	1.31 ± 0.04	0.83 ± 0.08	1.18 ± 0.04	0.64 ± 0.02

The rate of prothallial development was compared between the two forms. The growth of the apogamous gametophytes is faster with or without sucrose (*Table I*) than is the growth of the sexual. In both forms prothallial growth is greater with sucrose in the nutrient medium than without it. The prothalli of the asexual form initiated apogamous sporophytes in a shorter period of time and on smaller prothalli than the gametophytes of the sexual form produced archegonia (*Table I*). On the 26th day after sowing the spores, 50% of the gametophytes of the asexual form on 0% sucrose had initiated apogamous sporophytes and none of the prothalli of the sexual form had produced archegonia. Five days later only 21% of the gametophytes of the sexual form had archegonia on 0% sucrose. With 1% sucrose, 79% of the gametophytes of the asexual form had apogamous developments and 21% of the gametophytes of the sexual form had archegonia on the 26th day. The presence of sucrose in the medium caused apogamous sporophytes and archegonia to be initiated sooner and on smaller gametophytes than without sugar (*Table I*). Thus gametophytes of the apogamous form were more efficient than those of the sexual form with or without sugar in the medium.

The findings of the present study on spore size and sculpturing confirm the reports of Wagner et al (1965) and Pickett and Manuel (1925). The growth of the gametophytes of the apogamous form in sterile culture is somewhat different from the growth on soil as reported by Pickett and Manuel (1925). The gametophytes in sterile culture have a shorter filamentous stage and the apogamous plant is initiated two months sooner than the gametophytes in soil culture. The development of the apogamous sporophyte from the gametophytic cells behind the apical notch appears to be the same under both conditions. Spore germination, gametophyte growth, and apogamous sporophyte initiation were faster in sterile culture than on the soil cultures of Pickett and Manuel.

The size differences between the spores and antheridia support the findings of Manton (1950) and Whittier (1966). Manton has reported that the diameter of spores and antheridia increases with an increase in the level of ploidy in *Osmunda*. Size differences between the apogamous and sexual form appear to be due to the difference in the chromosome number and not to the mode of sporophyte reproduction.

The promotion of gametophyte growth and the formation of apogamous plants on smaller prothalli earlier with sugar in the medium has been reported by Whittier (1964, 1965) in other fern genera. Since the initiation of archegonia was also accelerated by sugar, it appears that sugar similarly affects gametophyte development in both forms. The earlier conclusion (Whittier, 1964, 1965) that sugar brings about the conditions necessary for apogamy, and in this case archegonia, by affecting carbohydrate metabolism and the availability of respiratory substrate appears also true for *P. glabella* var. *glabella*.

In discussions of apogamy in ferns (Tryon & Britton, 1958; Stokey, 1948; Whittier, 1965) it has been noted that water for sperm movement is not required for apogamous reproduction. Gametophytes of an apogamous species can grow and produce sporophytes using only capillary water from the soil. Sporophytes cannot form by fertilization on gametophytes with mature sex organs with only capillary water (Duncan, 1941) because a film of water is necessary for sperm movement to the archegonium. Earlier investigators (Hayes, 1924; Stokey, 1948; Tryon & Britton, 1958) noted the advantage that apogamous species have in drier habitats because this additional water is unnecessary.

In *P. glabella* var. *glabella* apogamous reproduction has other advantages over sexual reproduction. The spores of the apogamous form germinate sooner and the prothalli grow faster than the sexual form. Of more importance is the initiation of the apogamous sporophyte before archegonia are initiated on the gametophytes of the sexual form. This initiation occurred on about 50% of the gametophytes before archegonia were formed on any of the gametophytes of the sexual form. Archegonia were formed shortly after the initiation of apogamous sporophytes but the presence of archegonia on the gametophytes of the sexual form is not equivalent to the initiation of apogamous plants on the gametophytes of the apogamous form. Conditions conducive for fertilization do not necessarily occur immediately after the formation of mature archegonia. Thus, besides the advantage of only requiring capillary water, apogamous reproduction occurs faster than sexual reproduction in *P. glabella* var. *glabella*. Since the gametophyte is more susceptible to desiccation than the sporophyte, more rapid sporophyte formation is important because less time in the life history of the plant is spent as a gametophyte. The conclusion that apogamous reproduction is more rapid and more advantageous than sexual reproduction in *P. glabella* var. *glabella* is supported by the greater range of the apogamous form.

An explanation of the early maturation of the $4x$ gametophytes of the apogamous form is impossible at this time because in *P. glabella* var. *glabella* two variables are involved. The gametophytes of the apogamous form have the $4x$ chromosome level and an asexual method of forming sporophytes while the gametophytes of the sexual form are haploid and produce sex organs. Whether the differences between the prothallial growth and development of the two forms is related to the variation in chromosome number or mode of sporophyte formation awaits further study.

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The Gametophyte and Juvenile Leaves of Loxogramme

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Some years ago I described spore germination and prothallus development in two Indian species of *Loxogramme*, based on materials collected in the field along with samples of the sporophyte (Nayar, 1955). The prothalli were collected on the tufted, sponge-like root masses of *L. involuta* and *L. lanceolata*. It was soon evident that reporting mature prothalli as cordate possibly was a mistake. Since then I have made several attempts to raise pure cultures of *Loxogramme* prothalli in the laboratory and to review the nature and development of these prothalli.

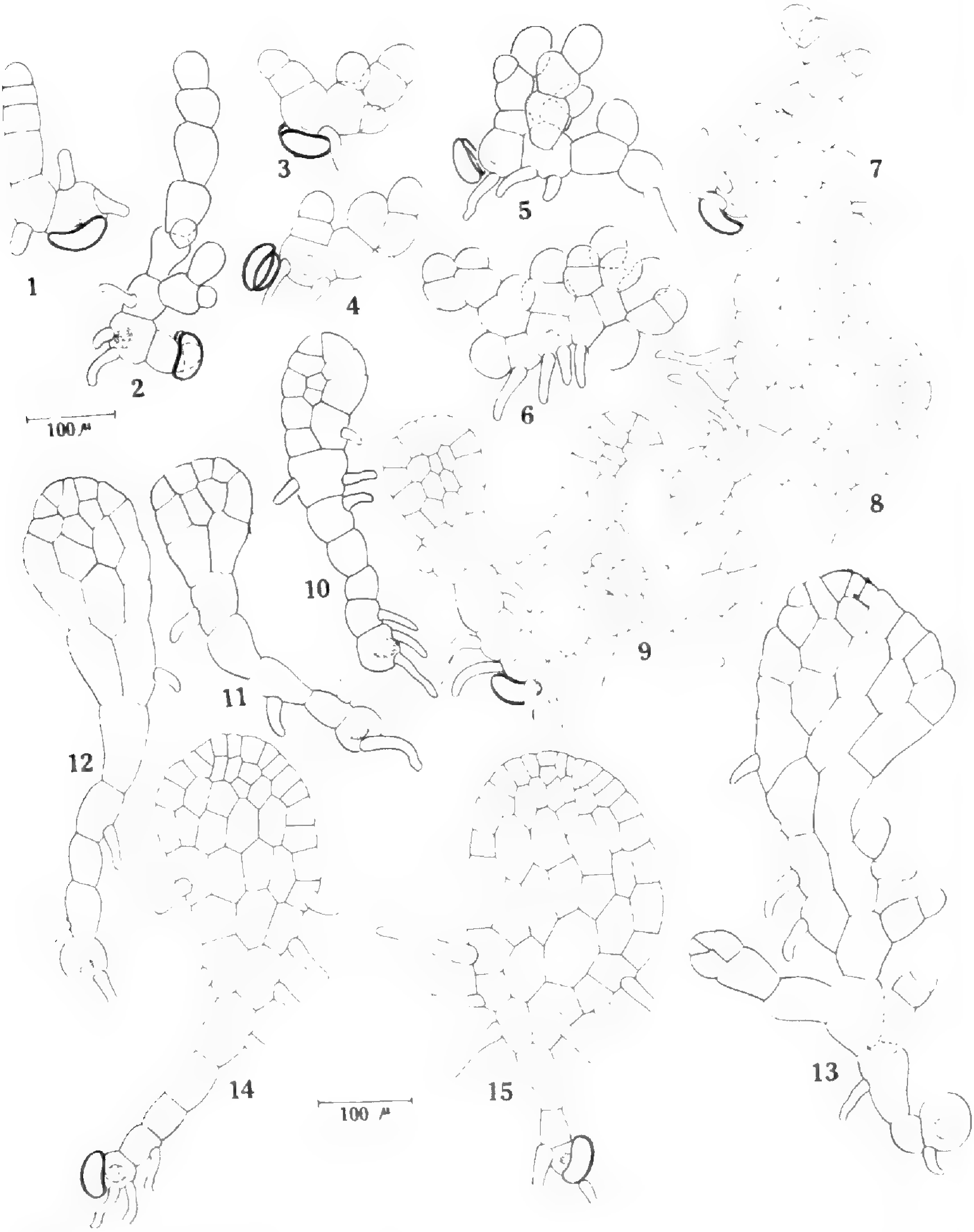
For this study spores of *L. involuta* (Blume) Presl and *L. lanceolata* (Swartz) Presl were collected during different years from various parts of Assam, mostly from the Khasi Hills. The spores were cultured on sterile nutrient agar at 24 ± 2°C and 600 ft-c. light intensity (Nayar, 1962). Prothalli at different stages of growth also were collected attached to their substratum and transferred to the laboratory. These were maintained in the laboratory under the same conditions of light and temperature as the agar cultures. No marked difference was noticed between the prothalli raised from spores and those collected in the field.

SPORE GERMINATION AND PROTHALLUS DEVELOPMENT

Morphology of the spores of several species of *Loxogramme*, including *L. involuta* and *L. lanceolata*, has already been described in detail (Nayar, 1963c, 1964; Nayar and Devi, 1964). The spores of *L. involuta* are monolete-bilateral, whereas in *L. lanceolata* both monolete-bilateral and trilete-tetrahedral spores occur mixed together (Nayar, 1963c). A perine is absent in both. Fresh spores contain many large plastids and a few deep yellow oil globules. As can be expected of thin-walled, chlorophyllous spores, those of *Loxogramme* cannot withstand desiccation. The spores remain viable for only a short time, and are difficult to culture in the laboratory. However, when sown fresh and when contamination is avoided, they germinate profusely in about two weeks. The oil globules in the spore become prominent and often coalesce into a centrally placed, large droplet; the plastids become deep green. Soon the spore swells and the exine breaks open at the laesura, partially exposing the deep green prothallial cell. A proximal rhizoid initial is soon differentiated, which grows into a short, achlorophyllous rhizoid. The rhizoids have a distinct violet-brown tinge in *L. lanceolata*. The prothallial cell, meanwhile, enlarges and protrudes as a thick papilla lateral to the rhizoid. The protruded portion is cut off by a transverse wall from the bulbous basal region, and by successive transverse divisions and elongation of the daughter cells develops into a uniseriate germ filament (*Fig. 1*). The basal cell of the germ filament is bulbous, and the oil globule persists for a long time in the basal cell. Oil globules are not generally found in the other cells of the germ filament. Rhizoid development is sometimes delayed on both species, for germ filaments devoid of rhizoids are quite frequent in the cultures.

By about two weeks after spore germination the germ filament is usually 3–5 cells long and is composed of deep green, barrel-shaped cells. Some of the proximal ones bear lateral rhizoids (*Fig. 1*) which are brownish in both species, and are usually very short in *L. lanceolata*. The germ filaments of *Loxogramme* are slow growing. Increase in length ordinarily results from the division of the terminal cell, or less frequently by division of the older cells. There is a strong tendency for the cells of the germ filament to elongate markedly. There are many growth irregularities in the germ filaments of *L. lanceolata*. Simple, elongate germ filaments, typical of *L. involuta*, are rare in those of *L. lanceolata* raised in culture. In many cases the germ filaments are branched; the branches develop laterally from some of the median cells (*Figs. 3–5*). In most cases the basal cell, which is the prothallial initial, bears several germ filaments, and in some cases the filaments are so crowded that the spore appears to germinate into an amorphous mass of cells (*Fig. 6*). However, the basal cell can easily be distinguished by its characteristic oil globule and larger size. In some cases the germ filament terminates in a rhizoid and stops growth when it is 2–5 cells long. Then lateral branches grow out into secondary germ filaments (*Figs. 5* and *9*), similar to those reported in *Christiopteris tricuspis* (Nayar, 1967). These secondary germ filaments may be branched in turn (*Fig. 7*) Rhizoids are produced profusely; often the basal cell bears 2–4 of them. Another peculiarity of the germ filaments of *L. lanceolata* is that they are moniliform. The cells usually have bulged sides (*Figs. 2* and *5*), but especially when crowded they may be pyriform (the anterior end broad and the posterior narrow). Most germ filaments grow erect or oblique to the substratum; branches form in all directions, giving the cultures a characteristic appearance.

Formation of a prothallial plate is initiated in the cultures



Spore Germination and Prothallial Plate Development in Loxogramme. Fig. 1. Germ filament of L. involuta. Fig. 2. Same, L. lanceolata. Figs. 3–7. Branched germ filaments of L. lanceolata. Fig. 8. Same, ca. 8 weeks old showing prothallial plate formation. Fig. 9. Same, ca. 10 weeks old. Figs. 10–12. Prothallial plate formation in L.

about 6–8 weeks after spore germination. The germ filaments are usually 5–8 cells long by then, but sometimes, particularly in *L. lanceolata,* there may be an extensive development of the filamentous stage. The distal cells of the germ filament, including the terminal cell, divide longitudinally, and the daughter cells expand laterally to form a dorsiventral prothallial plate (*Figs. 8* and *10*). Individual branches of the germ filament develop into separate prothalli (*Figs. 8* and *9*). About two weeks after the initiation of plate formation an obovate prothallial plate with a smoothly rounded or somewhat flattened distal end is formed (*Figs. 11* and *12*). Cells in the distal region are more actively meristematic and thus progressively smaller. The prothalli of *L. involuta* are comparatively quicker growing, and may develop into a prothallial plate 6–8 cells broad (*Figs. 14* and *15*) about two months after spore germination, whereas those of corresponding age in *L. lanceolata* are often only half as large (*Figs. 8* and *9*). Soon the prothalli become spathulate, and later the distal region expands markedly, making the prothallial plate broader than long (*Figs. 13* and *14*). Rhizoids are produced in profusion from the marginal cells at the posterior end.

The young prothalli of *Loxogramme,* unlike those of most leptosporangiate ferns, never develop a regular meristem or meristematic cell. In some cases, however, an obconical marginal cell is developed which acts for some time as a typical meristematic cell by cutting off daughter cells regularly on the oblique sides (*Figs. 14* and *15*), but its activity is never prolonged. About three months after spore germination the prothalli become nearly circular and about 2 mm in diameter, and are composed of small, densely chlorophyllous cells (*Figs. 16* and *17*). The cells are progressively smaller towards the distal margin. Superficial rhizoids similar to the marginal ones are produced on the posterior half. In *L. lanceolata* the prothalli exhibit a marked tendency to

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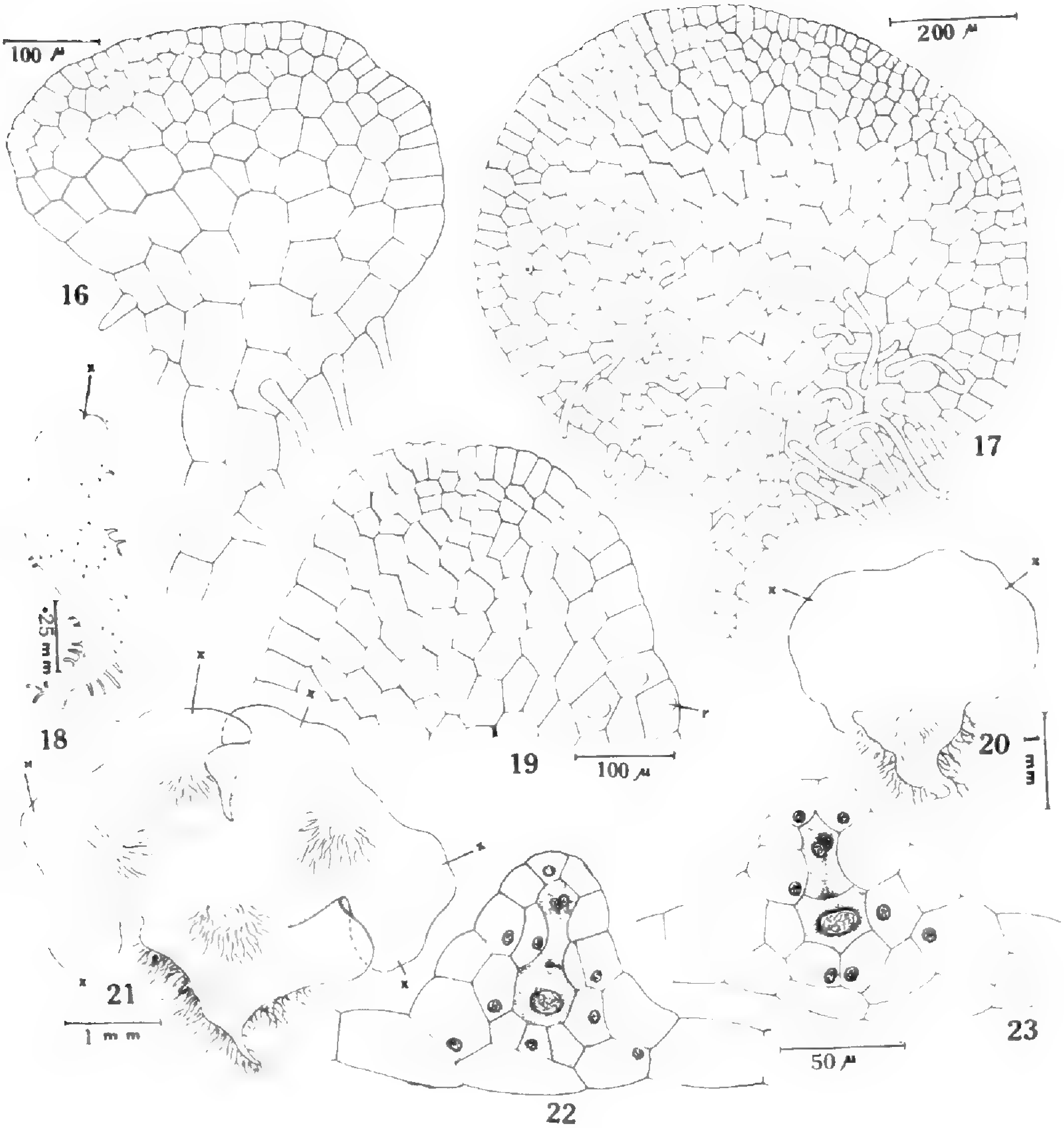
INVOLUTA. FIG. 13. SPATHULATE PROTHALLUS OF L. LANCEOLATA CA. 11 WEEKS OLD. FIGS. 14 AND 15. SPATHULATE PROTHALLI OF L. INVOLUTA CA. 2 MONTHS OLD SHOWING OBCONICAL APICAL CELL. THE SHADED AREAS REPRESENT OIL GLOBULES.

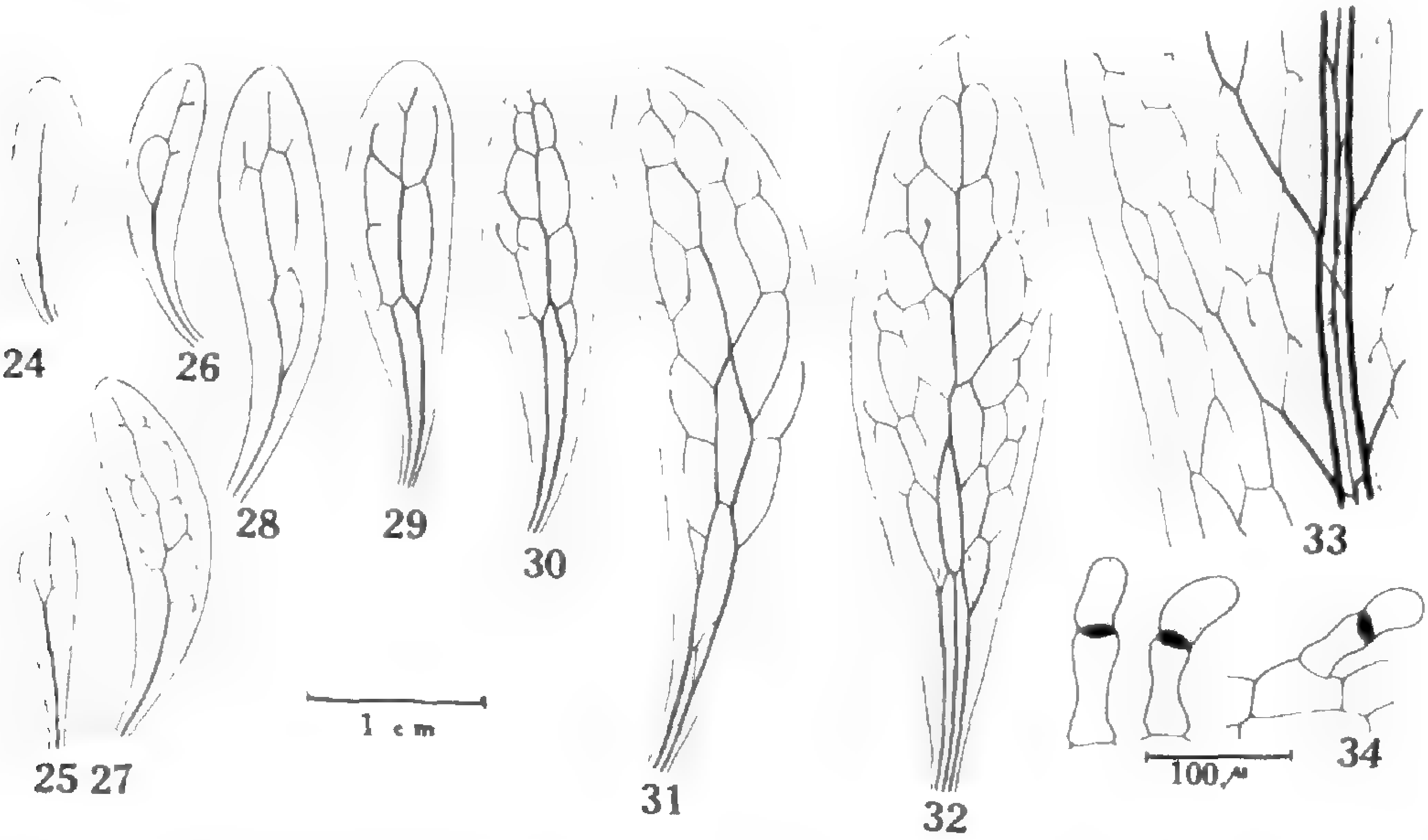


Young Prothalli of Loxogramme. Fig. 16. L. involuta, ca. 12 weeks old. Fig. 17. Same, ca. 15 weeks old. Fig. 18. Strap-shaped prothallus of L. lanceolata over 3 months old. Fig. 19. Same, apical portion. Fig. 20. L. involuta nearly 4 months old showing branching. Fig. 21. Same, nearly 6 months old. Figs. 22 and 23. Longitudinal section of archegonia of L. involuta. The abbreviation is: x = meristem.

elongate at this stage and soon become strap-shaped (*Fig. 18*). Rhizoids are produced all over the lower surface and are mostly aggregated in irregular patches; marginal rhizoids are developed profusely on the posterior half. In *L. involuta*, on the other hand, the prothalli expand and become irregular in outline and even irregularly lobed due to unequal marginal growth. The lobes develop into broad branches, often 3–10 at the distal end (*Fig. 21*). Occasionally only two lobes develop and the prothalli appear cordate (*Fig. 20*). There is no well defined meristem in these branches either; like the unbranched prothalli, the cells at the distal margin are smaller and divide more actively. Rhizoids develop on the lower surface and sometimes on the margins of the branches (*Fig. 21*). All prothalli are one cell thick throughout; in *L. lanceolata* they bear characteristically short rhizoids.

ADULT PROTHALLI

Further development of the prothalli is by diffused meristematic growth. The prothalli become ribbon-like and highly branched. Prothalli of both species grow slowly. In culture they remain one cell thick for nearly a year, and by then may be over 1 cm long. Sex organs are produced in patches superficially on the lower surface of the branches behind the growing apex. Antheridia are very sparse and are nearly always mixed with clusters of rhizoids. They are of the common polypodiaceous type, having a central mass of sperms surrounded by a 3-celled wall which is composed of a short, saucer-shaped basal cell, an annular cell, and a cap cell. Archegonia are found mixed with antheridia. Where archegonia are borne the thallus is 2–4 cells thick, forming a cushion subtending the sex organs. When archegonia are crowded, the cushions subtending individual archegonia merge to form a single broad patch usually two cells thick. Archegonia are initiated behind the growing apex of the branches where the thallus is still only one cell thick. The archegonial initial becomes slightly larger and its lower wall protrudes markedly from the surface of the prothallus. This cell divides transversely, making the prothallus two cells thick. The daughter cell on the lower surface of the prothallus divides again and develops into the archegonium in the usual way, forming a row of three cells. The outer one protrudes and develops into the neck, the middle one into the egg and neck canal cell, and the lower one into the basal portion of the venter. Mature archegonia (*Figs. 22* and *23*) are small and have a short, nearly straight, papilla-like neck composed of four tiers of three cells each. The neck canal cell is narrow and binucleate at maturity. The basal row of neck cells divides vertically towards maturity, making the neck two cells thick at the base, as in most advanced leptosporangiate ferns.



Juvenile Leaves of Loxogramme involuta. Figs. 24–32. Progression of venation pattern. Fig. 33. Portion of lamina from sporophyte, ca. 6 months old. Hatched area represents midrib. Fig. 34. Hairs of the first juvenile leaf.

Mature prothalli of *Loxogramme* are highly branched and ribbon-like. The branches usually have irregular, sometimes lobed sides. They presumably grow for years and form extensive patches. Some prothalli grown in cultures formed masses nearly 2.5 cm broad and had several crowded, lobe-like branches growing nearly erect after about two years. Much bigger masses were collected in the field. The prothalli remain one cell thick, except for irregularly placed areas where sex organs are borne. Midribs are absent, as are trichomes of all sorts.

JUVENILE SPOROPHYTES

As in other polypodiaceous ferns, the juvenile laminae of *Loxogramme* are simple and entire. The following description is that of *L. involuta* alone because juvenile plants of *L. lanceolata* were not available for study. The first few leaves have spathulate or strap-shaped laminae which taper downward to a narrow base (*Fig. 24*). A single, unbranched vein traverses the lamina and ends well behind the rounded apex. In succeeding leaves the vein is unequally 1- or 2-forked at the apex, and a midrib is differentiated by successive unequal forking and overtopping (*Fig. 25*). Such pinnately branched veins sometimes are found as early as the second or third juvenile leaf. Soon the basal lateral veins become forked (*Fig. 27*), and the branches (which face each other) of successive veins fuse to form areoles (*Figs. 26–29*). Sometimes the laminae are inequilateral with areoles only on one side of the midrib (*Fig. 28*). In some small leaves the single vein entering the lamina forks at the tip and the two branches form a terminal loop as in *Vittaria* (Wagner, 1952). A series of elongate, costal areoles develops on either side of the midrib of the laminae of larger, successive leaves (*Figs. 29* and *30*). Leaves from the fifth to seventh onward are supplied by a pair of parallel vascular strands, each of which bears the lateral veins of its side, and which fuse distally. Regular vascular commissures between the two main vascular strands form a row of narrow areoles which constitute the midrib of the leaf (*Fig. 31*). Meanwhile, the lateral veins become prominent, a second row of smaller areoles forms beyond the costal row (*Fig. 31*), and short, free-ending veinlets which point toward the midrib develop within the costal areoles from the outer vein of the areole.

Larger juvenile laminae develop several rows of areoles beyond the costal ones, and main lateral veins become more conspicuous. The midrib in these leaves has three main vascular strands (*Fig. 32*). A venation pattern quite similar to that of adult leaves is formed by plants nearly six months old (*Fig. 33*). In some cases early juvenile leaves are forked, with each lobe receiving a branch of the forked vascular strand entering the leaf base. Early juvenile leaves, including the first leaf, bear a few clavate hairs (*Fig. 34*) on the lower surface and on the margins. These hairs are bicellular, with a slender, elongate stalk cell and a rather swollen, probably glandular, densely protoplasmic terminal cell. They are similar to those reported on adult leaves (Nayar, 1955).

DISCUSSION

This study corrects an earlier report on prothallus morphology and growth in *Loxogramme* (Nayar, 1955). The prothalli are of the ribbon-like, branched type and develop not by the activity of an obconical meristematic cell, but from a diffuse meristematic area. Although the prothalli of *L. involuta* may approach a subcordate shape (*Fig. 20*), this is due to diffuse development of lateral branches by the cessation of the meristematic activity of the medianly placed cells at the apex, and not by the development of a median apical meristem as reported earlier; the branches ultimately become elongate and ribbon-like. The elongate, ribbon-like, mature prothalli are much like those reported in some microsorioid genera of the Polypodiaceae, e.g., *Kaulinia* (Nayar, 1963a), *Leptochilus* and *Paraleptochilus* (Nayar, 1963b), *Colysis* (Nayar, 1962), and *Christiopteris* (Nayar, 1967). So also are the juvenile leaves, with their simple, entire laminae traversed by a solitary vein, but which later develop a midrib by overtopping. These facts appear to support Holttum's (1947, 1949) belief that *Loxogramme* is polypodiaceous. In addition, the germ filaments of *L. lanceolata* occasionally branch profusely and stop terminal growth, while the lateral branches develop into individual prothalli, similar to those of *Christiopteris tricuspis* (Nayar, 1967). In many cases *L. lanceolata* produces several aggregated, branched germ filaments from a single spore.

Loxogramme is sometimes considered a grammitid fern. But the prothalli of Grammitidaceae are basically cordate albeit narrow, elongate, and often strap-like (Stokey and Atkinson, 1958). They also bear characteristic trichomes, which are highly branched and glandular or elongate and acicular. A midrib, which is sometimes interrupted, is found in all. Branching of the prothalli is uncommon. An apical meristematic cell is regularly formed during early stages of prothallus development. This is replaced by a multicellular meristem. The prothalli multiply vegetatively by fragmentation of the germ filament. The antheridia possess slender, elongate, barrel-like basal cells. The early juvenile leaves of the grammitid ferns, insofar as known, have lobed laminae. All of these features differ from *Loxogramme*. However, the very slow prothallial growth rate, the protracted filamentous stage of *L. lanceolata*, the characteristic branching of the germ filaments, the tendency for one spore to produce multiple germ filaments, and the tendency toward moniliform germ filaments recall the prothalli of grammitid ferns. Probably these features are adaptations to similar environments.

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Shorter Notes

POLYSTICHUM ACROSTICHOIDES × LONCHITIS VERSUS P. × MARGINALE[1]—In the spring of 1952, W. H. Wagner, Jr., and D. J. Hagenah discovered the hybrid *Polystichum acrostichoides* × *lonchitis* in the Bruce Peninsula, Ontario. They described the morphology of this hybrid in great detail.[2] Since the hybrid does not have a formal taxonomic binomial, I propose the following in honor of Dale J. Hagenah, longtime student of ferns:

POLYSTICHUM × **hagenahii,** hybr. nov. Verisimiliter hybridus *P. acrostichoides* × *lonchitis,* major et ad *P. acrostichoidem* vergens. Frons lanceolata, pinnulis infernis paullum tantum reductis. Frons fertilis pinnulis parum differentiatis, vix sporiferis et gradatim minoribus et angustioribus quam sterilibus.

Polystichum acrostichoides × *lonchitis* W. H. Wagner & D. J. Hagenah, Rhodora **56:** 1–6. 1954. TYPE: Ontario, Bruce County, west of Cape Crocker Indian Reservation, base of low hummock about 20 yards from edge of woods, 1 large plant not far from parents, Fall, 1953, *W. H. Wagner & D. J. Hagenah s. n.* (DAO; isotype MICH). Another specimen collected from the same plant in the spring of 1952 by Wagner and Hagenah is preserved in the Herbarium of the University of Toronto (photo DAO).

About thirty years before Wagner and Hagenah's discovery, W. R. McColl described *P. lonchitis* f. *marginale* (Amer. Fern J. **14:** 107. 1924). There are four specimens of this in McColl's herbarium, which was given to the University of Toronto. Three of the specimens are labelled *Polystichum lonchitis* f. *marginale* McColl. They were collected in 1925 and 1937. The fourth is labelled *Polystichum lonchitis* × *marginale*?; this specimen, collected in 1923, carries the data: Woodford Road [10 miles from Owen Sound], in crevice, in sun and dust on roadside. These data are similar to those given by McColl when he described f.

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[1] Contribution No. 564 from the Plant Research Institute, Research Branch, Canada Department of Agriculture, Ottawa.

[2] Rhodora **56:** 1–6, pl. 1198. 1954.

marginale. Although the 1923 specimen was not designated as the type by McColl, it is the only specimen in that herbarium which was collected prior to 1924, so it must be regarded as the holotype.

At the time I discovered McColl's specimens I suspected that they might also be the hybrid described by Wagner and Hagenah. This I mentioned to Bernard Boivin, who, in his "Énumeration des plantes du Canada," published[3] the following under "Innovations Taxonomiques": "× *Polystichum marginale* (W. R. McColl) Cody stat. n., *P. lonchitis* (L.) Roth f. *marginale* W. R. McColl, Rhodora 56: 3–6. 1954." Because Boivin cited the Rhodora reference instead of the reference to McColl's paper, it is clear he intended to name Wagner and Hagenah's hybrid.

I have recently examined the McColl specimens and found that among other characters, the spores are full and of similar size and shape. Therefore, neither the holotype of f. *marginale* upon which *P.* × *marginale* was based nor the other three McColl specimens are of hybrid origin, and it follows that the correct binomial name for the hybrid is *Polystichum* × *hagenahii*.—W. J. CODY, *Plant Research Institute, Central Experimental Farm, Ottawa, Canada.*

A NEW BOLIVIAN COLLECTION OF THE RARE ELAPHOGLOSSUM CARDENASII.—During their recent visit to the Field Museum in Chicago, I showed Dr. and Mrs. Tryon a number of unidentified ferns, among which was a peculiar Bolivian specimen collected in December, 1966 by Roy F. Steinbach "entre los musgos sobre tallos de árboles, Km. 104, Camino Chapare, Depto. Cochabamba, 3100 m." Dr. Rolla Tryon thought it could be *Elaphoglossum cardenasii*, a curious species described by Dr. Warren H. Wagner, Jr. (Bull. Torr. Bot. Club **81:** 62. 1954).

Although neither frond on the plant which we examined is fertile, further study proved without question that it is indeed *E. cardenasii*, a strange pedately-lobed species first collected by Dr. Martín Cárdenas in November, 1940, along the "Way from Cochabamba to Chimoré, about Km. 120; Province of Chapare,

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[3] Nat. Can. **93:** 253–273. 1966.

Department of Cochabamba, Bolivia, 2000 m." Although both collections come from the same general area, the new station is distant enough and the lobing of both collections uniform enough to make it unlikely, as Dr. Wagner concluded, that the fronds of the original plant represent an abnormality.

Our *Steinbach 630* has two fronds arising from the suffrutescent rhizome, along with several bases of broken stipes. The larger frond has a stramineous stipe 42 cm long, with a central lobe 20 cm long and 2.1 cm wide, at the base of which are borne two smaller, lateral lobes, one on either side, each of these being thrice-lobed, nearly to base. The second frond, which apparently is an immature fertile one, has a stipe 50 cm long, and is divided much like the sterile one, but the central lobe is only 5 cm long and 0.4 cm wide and the lateral lobes are proportionately reduced.

Dr. Wagner points out that "it would be desirable . . . to find the early leaf stages which show at what stage in the progression of leaves the unique foliar organization arises." Unfortunately the Steinbach specimen in hand does not help in solving this problem, but perhaps now we can be optimistic that more *E. cardenasii* will turn up in future collections.—ROBERT G. STOLZE, *Field Museum of Natural History, Chicago, Ill. 60605.*

TRICHOMANES PETERSII IN THE BOSTON MOUNTAINS OF ARKANSAS.—Field studies (under National Science Foundation Grant GB-4095 to P. L. Redfearn) of the bryophytes of the Interior Highlands of North America have resulted in the discovery of *Trichomanes petersii* A. Gray in Arkansas. Like *T. boschianum,* which was reported from Arkansas by Clark,[1] this species is associated with relic mixed mesophytic forest common there.

The population of *T. petersii* occurred at the base of a massive sandstone boulder along the bottom of a narrow ravine that is a tributary to Indian Creek, ca. 3 miles SW of Sandgap in Pope County, sec. 16, T12N, R20W (*Redfearn 21412*, MICH, NCU, SMS, US, UT). Plants grew near the base of the boulder and consequently were subject to inundation by rapidly flowing water

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[1] Amer. Fern J. **52**: 85–86. 1962.

during periods of excessive rainfall. The narrowness of the ravine also suggests that they are never exposed to direct sunlight.

This first record of *Trichomanes petersii* from Arkansas constitutes a very large range extension, the nearest locality being in Franklin County in northwestern Alabama, more than 300 miles away. Although these plants belong taxonomically to *T. petersii* as presently understood, they do have characteristics peculiar for this species and quite different from other populations of this species from the eastern United States. The blade bases approach a subcordate condition, as opposed to the typically more acuminate base. The length/width ratio of the blade is smaller than in the typical form; and there is a strong tendency for the midrib to branch dichotomously so that the blade often has two sori, or rarely more. Although these differences in the Arkansas plants may be genetic, it is possible they are due to environmental factors, perhaps damage of the blade apices. Consequently, culture studies of these plants are in order, and living materials are now undergoing investigation at the University of Michigan Botanical Gardens.—DONALD R. FARRAR and PAUL L. REDFEARN, JR., *University of Michigan Botanical Gardens, Ann Arbor, Mich. 48105* and *Southwest Missouri State College, Springfield, Mo. 65802.*

Notes and News

THE AMERICAN FERN SOCIETY ANNUAL MEETING this year will be with the A.I.B.S. at Columbus, Ohio, home of Ohio State University. Dr. Jane Decker will be our local representative. We plan a foray on September 1 and 2. Foray headquarters will be at the Holiday Inn, Chillicothe, Ohio 45601. For reservations, write to the Inn (identifying yourself as a foray participant) or to Dr. Clara Frederick, Urbana College, Urbana, Ohio 43078. On September 3 we will have a Society luncheon, which will be followed by a program of papers. Dr. W. H. Wagner, Jr., Botanical Gardens, University of Michigan, Ann Arbor, Mich. 48105, is the program chairman. Contributors should send titles, abstracts, and projection equipment needs to him immediately.—I.W.K.

18TH ANNUAL SPRING WILDFLOWER PILGRIMAGE.—Plan now to spend April 25–27 in the Great Smoky Mountains at the peak of the spring wildflower season. Although wildflowers will be the principal attraction, Dr. A. Murray Evans, of the University of Tennessee, will lead several fern walks. Motorcades and trail hikes under expert leadership will be offered. Early morning bird walks are planned, as are evening lectures, one of which will be Dr. Evans' "Ferns of the Appalachians."

Participants should register beginning at 9 AM on April 25 in the Gatlinburg Civic Auditorium. The registration fee is $2.00. There are no advance registrations. Descriptions of the various events will be furnished at registration. For lodging information, write to Department W. P., Box 527, Gatlinburg, Tenn. 37738.

THE FIFTH ANNUAL TROPICAL FLOWER & FERN SHOW of the Los Angeles International Fern Society will be held in Brookside Park at Pasadena, California, on Saturday, May 18 (1:00 to 10:00 PM) and on Sunday, May 19 (10:00 AM to 6:00 PM). For further details write to Bee Olson, 13715 Cordary Ave., Hawthorne, Calif. 90250.—D.B.L.

Recent Fern Literature

THE SOUTHERN FERN GUIDE, by Edgar T. Wherry. Doubleday & Co., Garden City, New York, 1964. 349 pp. $4.95.—Through an oversight this important book by one of our Honorary Members has never been reviewed in the Fern Journal. The users of Dr. Wherry's well-known "The Fern Guide" (1961), which covered the northeastern United States, will find this new work familiar, for it follows exactly the same format, and even the same drawings are used when the species concerned occurs both in the northeastern states and in the south. The new illustrations have been drawn by the same artist, are very good, and will serve for the ready identification of all but the most critical species. In my opinion, one of the defects of the new work is that it does not cover all of the southern states as is implied by the title. The ferns treated are those occurring south of the Fall Line, from North Carolina south to Florida and west to Texas. Dr. Wherry notes that the ferns of the uplands of North Carolina, Georgia, and Alabama are the same as the more northern ferns treated in his previous "The Fern Guide." This is true, but nevertheless it would have been convenient to have a complete treatment of all the ferns of the southern states. It is true that Wherry mentions, and in some cases illustrates, these northern ferns in an "Appendix," but they are not included in the generic or specific keys, and are not even listed in the Index to the book. This will be a drawback, especially to the amateur. It is possible that this limitation was imposed by the Doubleday Company rather than being voluntary on Dr. Wherry's part, because even as it is the book must be rather expensive to print, with all of its illustrations.

At least some workers have been desirous of having a conservative fern guide to replace that of Small, but they will be disappointed with this, for Wherry recognizes not only most of the segregate genera recognized by Small but some additional ones. Wherry unquestionably knows these southern ferns very well, but he has fallen into the trap of making his generic decisions on the basis of the Florida species only. It is easy enough to recognize segregate genera on the basis of the few Florida representatives of widespread tropical groups, but it is not so easy when these groups are considered from a worldwide viewpoint. It is an essentially provincial attitude. It might be mentioned incidentally that Dr. Wherry lost an opportunity in not segregating the two species he refers to *Stenochlaena*, *S. kunzeana* and *S. tenuifolia*, for Holttum has indicated that the first of these is referable to *Lomariopsis*, a much better founded segregate than some of those that Wherry does adopt.

Commendably, the Polypodiaceae is kept in its traditional sense, but it is broken up into groups for which "family" names are suggested. Some of these appear to be highly artificial, such as *Stenochlaena*, *Acrostichum*, *Trismeria*, and *Pityrogramma* being grouped into the "Gymnogrammaceae." A nomenclatural error is the restriction of the "family" name Pteridaceae to *Pteridium* while the type of the family, *Pteris*, is referred to the "family" Sinopteridaceae. A taxonomic error is the inclusion of *patens, augescens, normalis* and some other more doubtful species like *versicolor* in *Thelypteris*, although in their characters (including chromosome numbers) these are surely referable to *Cyclosorus*, as Christensen indicated long ago; in fact at least some of them probably hybridize with *Cyclosorus dentatus*. Incidentally, Wherry recognizes *quadrangularis* as a species distinct from *dentatus*, for the first time, so far as I know, for any United States plants. I have tried to follow Alston's suggested distinctions, but they always fail, with African as well as American material.

One weakness is Wherry's desire to provide "common" names for all the species, an idea that goes back to the first edition of Britton and Brown's Illustrated Flora, where common names were invented for all the species, some of them manifestly atrocities. The late Paul C. Standley, when thinking of a local field trip, is reputed to have asked, "Shall we go out and collect Knieskern's smooth-fruited beak-rush?", referring jokingly to the name assigned in Britton and Brown to *Rhynchospora knieskernii*. Botanists are now generally agreed that it is impossible to get the public to agree on an artificially coined "common" name, and such names have been omitted from the latest Britton and Brown and Gray's Manual. Some of those coined by Wherry are almost unbelievable: "Free-tip star-hair fern," "Toothed lattice-vein fern," "Alabama streak-sorus fern," "Grid-scale maiden fern," "Twin-spore-stalk fern," or "Spready tri-vein fern." I leave the reader to guess, if he can, which species receive these appellations.

One other matter is of some technical importance. On page 346 of the book are published seven new combinations, with the note: "These combinations are also published in periodical literature." Indeed, they were published in the American Fern Journal, vol. 54, pp. 144–146. But this particular number of the Journal came out November 12, 1964, whereas the Southern Fern Guide, which is dated merely 1964, was officially published on October 2, 1964. Thus, the new combinations date from it, not from the Journal.

Wherry spells some specific epithets *ferrissi*, *engelmanni*, *chapmani*, and so forth. He justifies this in the introduction by saying that he adopts the original spelling, not feeling competent to correct the Latin of earlier workers. This is a misapprehension, because no knowledge of Latin is required. The International Code of Botanical Nomenclature specifies that epithets that are genitives of names ending in consonants add "ii," except after "-er," and further that names published originally with other endings are to be treated as orthographic errors and corrected, in these instances to *ferrissii*, *engelmannii*, and *chapmanii*. The amateur or general botanist does not know this and so it is up to a professional like Wherry to adopt the correct spelling. One peculiarity is the reference to the younger Linnaeus as "L. Jr.," but I suppose that this is as good Latin as the usual "L. fil."

Wherry has included a good deal of additional information which will be of value, such as the meaning of specific names, basic chromosome numbers, references to other books on ferns, an article on the life cycle of ferns, notes on fern culture, and incidental notes on a number of cultivated species of ferns.

Some of my remarks above may seem to indicate that I am very critical of this new work. I do wish that it were better in some respects, but nevertheless this is a fine book, the work of a dedicated botanist, and it is going to be the working guide for all students of the southern ferns for many years to come.—C.V.M.

American Fern Society

Report of the President for 1967

One of the highlights for members of the American Fern Society is the annual meeting in association with the American Institute of Biological Sciences in the summer, which provides an opportunity for fern enthusiasts to get together in an informal manner, to discuss ferns from various points of view, and to observe them in their native habitats. The August field trip to the Edwards Plateau in Texas was exceptionally rewarding, and those who attended left with a much better understanding of the habits and habitats of our western ferns. Dr. and Mrs. Donovan S. Correll, both authorities on the Texas Flora, arranged and led a magnificent trip. We were most comfortable and pleased with our headquarters at the friendly Lazy Hills Guest Ranch, where excellent food, swimming, and horseback riding were provided. We were especially thankful for their showing us, in such a limited time, a large number of Texas ferns in their varied habitats. We drove on a highway in a river bottom where we could see ferns on the wet banks, climbed a mountain with ferns along the rocky crevices, found *Isoëtes* in shallow pools on the mountaintop in close proximity with cactus (*Opuntia*), and on the very last trip were thrilled with the discovery of a colony of *Ophioglossum*.

We were fortunate in having Dr. Frank W. Gould as our representative at College Station, who arranged for a delightful luncheon and an air-conditioned program room with remote controlled projector.

The planning committee which serves as liaison between the Society and the National Committee of the XIth International Botanical Congress is well under way with plans for field trips and a program on ferns. The adherent societies in AIBS are helping to finance the Congress and also to request that commerative postage stamps be issued for it.

A second index is being planned for the American Fern Journal, starting with 1936.

We wish to thank Barbara Joe Hoshizaki for acting as Judge of Elections and Mrs. Pearth who served as auditor.

It has been a privilege and an honor to serve the Society for the past two years. I am indebted to the members of the Society and especially to the Council for their enthusiasm, constructive ideas and cooperation. The continuing of all of the other members of the Council, with the addition of the new Vice-President who has worked so willingly and efficiently for the Society, insures an excellent year for 1968.

Respectfully submitted,

MILDRED E. FAUST, *President*

Report of the Secretary for 1967

Membership in the American Fern Society at the end of 1967 stands at 671, of which 83 are members from 29 countries abroad. In the United States, only the Dakotas, Nevada, and New Mexico are not represented.

I report with regret the death of 7 members: Miss Edith Scamman, a member since 1937 and secretary of the Society in 1950 and 1951; Miss Claudia Schmidt, also a member for 30 years; Mr. Thorleif Fliflet and Dr. C. M. Van de Water, both members for 20 years; Mr. Ralph S. Hudson, since 1961; Mr. George L. Kirk, since 1961; Mrs. Thomas S. Christensen, since 1965.

The annual meeting of the Society, held August 29 with the American Institute of Biological Sciences on the campus of the Texas A & M University, was preceded by a luncheon attended by 26 members and presided over by President Mildred E. Faust. There were also 26 at the afternoon session, with Dr. Faust presiding. The titles of the papers presented are: "Natural history of *Equisetum* in Costa Rica," by Richard L. Hauke; "The gametophytes of *Taenitis blechnoides* (Willd.) Swartz and *Syngramma pinnata* J. Sm.," by Lenette R. Atkinson; "Asexual reproduction in two species of Hawaiian ferns," by Richard A. White; "Spore morphology as an aid to classification of Malaysian ferns," by James E. Canright; "The fern foray in retrospect," by Donovan S. Correll; "The present status of the Hart's Tongue fern in central New York," by Mildred E. Faust.

Four of the five Council members were present at a meeting August 29. Dr. Warren H. Wagner, Jr., reported that his liaison committee between the American Fern Society and the XIth International Botanical Congress in Seattle in 1969 (Dr. Wagner, chairman, Dr. T. M. C. Taylor, and Dr. Arthur R. Kruckeberg) has made tentative plans for our society's participation in the Congress. Dr. Wagner stressed the desirability for individual contributions toward financing the Congress, which has been noted in this JOURNAL **57**: 183. 1967.

Respectfully submitted,

LENETTE R. ATKINSON, *Secretary*

Report of the Treasurer for 1967

In 1967 receipts were just slightly over expenses; the large balance of last year kept us well out of the red. Cash on hand at end of year was about $6.00 more than that for 1966. Receipts from sale of back numbers exceeded those of 1966 by $224.00. Royalties from Dr. Wherry's books exceed those of 1966 by $52.00.

Advance dues this year were $127.00, much less than in 1966, but advance subscriptions were $826.40, which is much more than that received in 1966.

Income from advertisements in the JOURNAL was $4.00 less than in 1966, but voluntary plate and page charges, instituted this year, gave us $180.00 income.

The spore exchange netted $51.49 beyond expenses.

Receipts

Cash on hand, January 1, 1967			$2,829.79
Membership Dues			
Renewals	$812.60		
Sustaining	64.00		
New	392.20		
Advance	127.00		
Arrears	28.00		
		$1,423.80	
Subscriptions			
Current	$324.90		
Advance–1968	774.40		
Advance–beyond 1968	52.00		
Arrears	31.97		
		1,183.27	
Sale of Back Numbers		1,437.49	
Sale of Reprints		352.07	
Royalties (Wherry's Books)		438.49	
Gifts		3.69	
Page and Plate Charges		180.00	
Advertising in Journal		94.70	
Spore Exchange		51.49	
Miscellaneous		5.00	
Contribution to Intern. Bot. Congress		100.00	

Total Receipts	5,270.00
Total	$8,099.79

Disbursements

American Fern Journal			
Vol. 56, No. 4	$1,120.65		
Vol. 57, No. 1	926.37		
Vol. 57, No. 2	926.79		
Vol. 57, No. 3	947.14		
		$3,920.95	
Reprints and postage		416.19	
Envelopes for mailing journal		89.00	
Printing stationery		95.30	
Treasurer's expenses		89.20	
Secretary's expenses		96.99	
Editor's expenses		54.54	
Foray expenses		53.87	
Shipping and handling back numbers		0.00	
AIBS dues		400.00	
AAAS dues		10.00	
Purchase of back issues		16.93	
Book exhibit		17.50	
Miscellaneous		4.00	
Total disbursements			$5,264.47
Cash on hand, January 1, 1968			$2,835.32

Statement, December 31, 1967

Assets

Cash in Union National Bank	$2,835.32	
Cash in Green Point Savings Bank		
Bissell Herbarium Fund	977.66	
Life Membership Fund	1,529.26	
Una Weatherby Fund	4,132.01	
Accounts Receivable	197.06	
Inventory, Journal	7,103.90	
Library	396.00	
Total		$17,171.21

Liabilities

Advance Dues	$ 127.00	
Advance Subscriptions	826.40	
Fund Balances		
Bissell Herbarium Fund	977.66	
Life Membership Fund	1,529.26	
Una Weatherby Fund	4,132.01	
General Fund	9,578.88	
Total		$17,171.21

Respectfully submitted,

LEROY K. HENRY, *Treasurer*

Report of the Auditing Committee

I hereby certify that I have seen the books and accounts of Dr. LeRoy K. Henry, Treasurer of the American Fern Society, Inc., and have obtained confirmation of the correctness of the Society's balances on hand as set forth in detail in the accompanying report of the Treasurer.

DOROTHY L. PEARTH, *Auditor*

Report of the Judge of Elections

The results of balloting for officers of the American Fern Society are as follows:

For President	
Irving W. Knobloch	316
Warren H. Wagner	2
For Vice-President	
Warren H. Wagner	313
Richard Hauke	2
J. L. Edwards	1
Clyde F. Reed	1
Alice Tryon	1
David B. Lellinger	1

For Treasurer

LeRoy K. Henry	315
Walter S. Phillips	1

I therefore declare the following candidates elected to office: Irving W. Knobloch, President; Warren H. Wagner, Vice-President; LeRoy K. Henry, Treasurer.

Respectfully submitted,

BARBARA JOE HOSHIZAKI, *Judge of Elections*

Report of the Fern Spore Exchange

The Fern Spore Exchange is continuing to grow. Many new requests were made for the Fern Spore Exchange list. This list now reaches eleven National Parks or Botanic Gardens in as many different countries. The fern societies of England and Japan both contribute to the Exchange, as do other institutions and individuals throughout the world.

A supplementary list will be issued in a very short time, which will include many species that are completely new to the Exchange. The current list should be retained, as eighty percent of the listings are either 1966 or 1967 collections. The two lists will contain about 380 species and varieties.

The Fern Spore Exchange depends on the continuing support of all the members of the Society. Its success is due to the faithful members who consistently contribute fresh spores year after year. No matter how common a particular species is, it may be the particular species required for research in some other area of the world. All contributions to the Exchange are appreciated and sincere thanks are tendered to each contributor.

Exchange lists will be supplemented in October of each year. A fresh stock of spores or fertile fronds should be collected when ripe and sent to the Exchange before that date in order to be included in the list. The Exchange is a continuing service, of course, and spores are received and disbursed throughout the year.

Respectfully submitted,

NEILL D. HALL, *Director of the Spore Exchange*

Report of the 1967 Fern Foray

The 1967 Fern Foray was held in central Texas in conjunction with the AIBS meetings at College Station. The Foray was organized and conducted by Dr. Donovan Correll.

The group assembled at the Lazy Hills Guest Ranch, Ingram, Texas, on Thursday afternoon August 24, 1967. We were treated to a delicious Texas-style barbecue; then Dr. Correll took us on a botanical tour of Texas via his beautiful color slides.

Early the next morning we set out to see some of the flora for ourselves. The first day was spent on the limestone of the Edwards Plateau. The first fern we saw was the southern maidenhair, *Adiantum capillus-veneris*, growing profusely along the Guadalupe River. We proceeded to drive up the river bed to a parking area, where we hiked up a small side canyon. Several ferns grew on the canyon walls, and the orchid *Epipactis gigantea* was in fruit here also. On a ledge above the path some *Selaginella wrightii* was spotted. In trying to get some of it down with a stick, Dave Emory discovered that he was standing about three feet from a rattlesnake.

After a rest stop at Leakey, we drove to Prade Ranch, at the source of the Rio Frio. After lunch we explored the area, finding several ferns along the river and among rocks above. In the river bed at this point are ruts in the limestone made by Conestoga Wagons. We proceeded to Garner State Park and climbed a rocky hillside. The climb was hot, but well worth it, as several new ferns were added to our list. We returned via a different route to the ranch in time for supper, after which several members showed slides and Dr. Correll led us in an enjoyable songfest.

Saturday morning, fortified by a delicious cook-out breakfast of eggs, bacon, and pancakes—all you could eat, we set out for some granite outcrops. The first stop was Enchanted Rock, a pink granite dome. In ledges on the mountain we saw several species of *Cheilanthes*, *Pellaea*, and *Selaginella*. At the top were pools containing *Isoëtes lithophila*, growing like grass in a lawn. The white rainlily, *Zephyranthes drummondii*, was abundant here also.

After lunch we drove to another granite area, Balanced Rock. Here many of the same ferns as at Enchanted Rock grew to larger size. One of the highlights of the trip came when Mrs. Krauss discovered that she was standing in a patch of *Ophioglossum engelmannii*. This represented a new county (Burnet) and a new floristic region (Edwards Plateau) for this species in Texas.

On Sunday we had time to explore the Lazy Hills Ranch (the more adventuresome on horseback) before leaving for College Station.

Dr. and Mrs. Correll did a splendid job of planning an interesting trip for us. We saw 21 species of ferns, a good number for an arid region, and most of them were new to many of us. They also did a marvelous job of estimating how long it would take to cover the ground; we never felt rushed and had ample time to explore and collect. Directions printed in advance were most helpful. Dr. Correll also identified nearly any plant, fern or not, so we became well acquainted with the flora. Our thanks also to the folks at Lazy Hills Guest Ranch for providing us with very comfortable quarters, delicious food, and the facilities at their spacious ranch (that pool sure felt good after a hot day in the field!). In short it was a well organized and very enjoyable Fern Foray.

The 21 species seen were: *Selaginella peruviana*, *S. riddellii*, *S. wrightii*, *Isoëtes lithophila*, *Ophioglossum engelmannii*, *Anemia mexicana*, *Adiantum capillus-veneris*, *Cheilanthes alabamensis*, *C. eatonii*, *C. horridula*, *C. kaulfussii*, *C. lindheimeri*, *C. tomentosa*, *Notholaena candida* var. *copelandii*, *N. parvifolia*, *N. sinuata* var. *integerrima*, *Pellaea atropurpurea*, *P. ovata*, *P. wrightiana*, *Thelypteris normalis*, and *Woodsia obtusa*.

Participants in the foray were from ten states: Dr. and Mrs. Correll (Texas), Mr. Robert Aborn (N.J.), Mr. William Adams (Ohio), Mr. David Emory (Penna.), Dr. Mildred Faust (N.Y.), Dr. and Mrs. Norman Foster (Texas), Mrs. Alice Gobin (Calif.), Dr. Aaron Goldberg (D.C.), Dr. and Mrs. LeRoy Henry (Penna.), Dr. Donald Huttleston (Penna.), Mr. Ray Jordan (Texas), Dr. Irving Knobloch (Mich.), Mrs. Beatrice Krauss (Hawaii), Dr.

James Montgomery (N.J.), Miss Eva Sobol (N.Y.), and Miss Ann Stewart (Mass.)—JAMES D. MONTGOMERY, *Biology Department, Upsala College, East Orange, New Jersey 07019.*

New Members

Mrs. Arnold Abercrombie, Box 545, Atlantic Beach, Fla. 32005
Mr. Shripad N. Agashe, Botany Dept., Shivaji University, Kolhapur, India
Mr. Julian P. Boyd, Bear Tavern Road, R. D. 1, Titusville, N. J. 08560
Mrs. J. Hammond Brandt, Upper Falls, Md. 21156
Mr. Alvin R. Breisch, Biology Dept., State Univ. of N. Y. at Albany, Albany, N. Y. 12203
Mr. Ralph E. Brooks, 5611 Maple St., Shawnee Mission, Kansas 66202
Mr. Fred L. Bussa, 6203 New Castle Dr., Bellaire, Texas 77401
Mrs. John Carden, 4208 Corona St., Tampa, Fla. 33609
Sister Rose D. Cardillo, Asst. Prof. of Biology, Ladycliff College, Highland Falls, N. Y. 10928
Miss Mireya D. Correa, U. S. Army Tropic Test Center, P. O. Drawer 942, Miraflores Annex, Fort Clayton, Canal Zone
Miss Clara Crenshaw, The Ridge, Greenville, Ala. 36037
Mrs. Joseph Decroo, 216 W. 11th Ave., Tarentum, Pa. 15084
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Mrs. G. Nettie Scorp, 84 Christopher St., Lodi, N. J. 07644
Mr. William L. Scriven, Nurseries & Fruit Growers, Marriottsville Rd., Randallstown, Md. 21133
Mr. Clifford W. Smith, Dept. of Botany, University of Hawaii, Honolulu, Hawaii 96822

Mrs. Margaret Sprecher, 2621 N. Myers St., Burbank, Calif. 91504
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Miss Mary K. Story, 10371 Topeka Dr., Northridge, Calif. 91324
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Mr. John W. Zelley, 1014 Columbus Rd., Burlington, N. J. 08016

Changes of Address

Mr. Richard A. Benedict, 1773 Monroe Ave., Seaford, N. Y. 11783
Dr. F. M. Breed, 4 Hadsell Court, Binghamton, N. Y. 13901
Mr. William G. Carr, 2231 Derek Drive, Fullerton, Calif. 92631
Mr. Carl F. Chuey, Biology Dept., Youngstown State University, Youngstown, Ohio 44503
Mr. Boughton Cobb, Falls Village, Conn. 06031
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Mrs. W. Brooks Evert, 115 N. Lakeside Dr., Medford, N. J. 08055
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Mrs. Ronald S. Gray, R.F.D. #2, Derry, N. H. 03038
Mrs. Winifred J. Harley, Bolton Road, Harvard, Mass. 01451
Dr. R. E. Holttum, 50 Gloucester Court, Kew Road, Richmond, Surrey, England
Mr. Paul C. Hutchison, California Botanic Garden, Rt. 2, Box 5098, Escondido, Calif. 92025
Miss Mary Howard, Ridgewood Ranch, Willits, Calif. 95490
Mr. John P. Knabel II, 9117 Cherbourg Dr., Potomac, Md. 20854
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Ferns and Fertilizer

BARBARA JOE HOSHIZAKI

Horticultural knowledge concerning the fertilization requirements of ferns is far greater than the literature indicates. Experienced fern growers have known for a long time that proper fertilization of ferns enhances their growth and beauty. Equally well known is the fact that ferns suffer readily from improper fertilization. Considering these two points, the complex reactions between plants and soil, and the reports of individual gardeners, the result is a confused potpourri of advice. Much of what is written by individual gardeners is solid, practical advice, but many times it is applicable only to a particular fertilizer or soil mix, pattern of watering, quality of the water, or other specialized condition. There is a need for trained personnel to ascertain through controlled studies more precisely the response of ferns to mineral needs. This information would be of great interest not only to the horticulturists, but also to ecologists and others who deal with ferns as experimental material. The diversity of fern habitats, which ranges from tree tops to rocks to heavy clay soils, opens up a whole field of possible investigations on soil and mineral studies. However, this paper is written with the needs of the amateur fern grower in mind, and concerns some of the basic practices and principles in providing minerals to ferns through fertilization.

WHICH FERNS NEED FERTILIZATION?—All the cultivated ferns known to me benefit from proper fertilization by growing faster, larger, or both. Ferns do differ in their responses. As a whole, ferns require less fertilization than most cultivated seed plants.

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WHAT HAPPENS IF FERNS ARE OVER-FERTILIZED? -Stunting, yellowing, and, more commonly, burning or browning of the foliage, wilting of the fronds due to root damage, and in severe cases death of the plant may occur. These reactions are primarily due to too much soluble salt from the fertilizer collecting on or near the plant tissue and indirectly damaging the tissue by dehydrating it.

WHAT ARE THE CONSEQUENCES OF NO FERTILIZER?—If the soil is of good quality and other conditions are favorable, ferns may not need fertilizers, and growth is usually steady and adequate. Less favorable conditions may result in stunting, slow growth, poor quality foliage, and susceptibility to disease.

WHAT KIND OF FERTILIZER SHOULD BE USED?—The amateur should use fertilizers that have a reputation for low burn. These fertilizers are available in forms to be applied as liquids or dry, Liquid types include fish emulsion (5-2-2), "Blue Whale" (6-2-1). "Orchid Spoonit" (30-10-10), "Hyponex" (7-6-19), and others. Forms applied as a powder or in granules include fish meal (9-3-0), cottonseed meal (6.4-1.5-1), "Milorganite" (6-3-0), hoof and horn (15-0-0), and others. The first of the three numbers listed after each fertilizer indicates the percentage of nitrogen (N), the second number the percentage of phosphorus (P), and the third the percentage of potassium (K). The percentage varies from brand to brand, but is always given on the label. Fertilizers having all three of these important mineral elements are termed complete fertilizers, as opposed to incomplete fertilizers, which lack one or more elements. Complete fertilizers are generally preferred over incomplete ones, but results vary from grower to grower, depending on the soil and cultural practices.

HOW SHOULD FERTILIZERS BE APPLIED?—Certainly the manufacturer's directions should be followed carefully. If you are uncertain about a fern's tolerance to fertilizer, there is no harm in reducing the fertilizer concentration to half. Fertilizers to be dissolved in water should be thoroughly dissolved before application. Fertilizers applied as a powder or granules should be sprinkled thinly and evenly over the moist soil surface, and the plants watered thoroughly *immediately* after application. Any fertilizer inadvertently spilled on the foliage should also be washed off immediately. If too much fertilizer is applied in one spot, especially on or near the crown of the fern, remove as much of the fertilizer as possible and water thoroughly. Not only will this reduce the possibility of burning the fern but will also reduce concentrations of mold growth. Fertilizers derived from organic substances may encourage microorganisms. Although such fertilizers must be decomposed by microorganisms before releasing most of their nutrients, very high concentrations of mold may be damaging to the fern crown and young fronds. Where warmth and high humidity occur, as in greenhouses, molds and bacteria may become particularly troublesome, especially with very young ferns. Under these conditions manures in particular should be avoided. Note that with ferns the surface of the soil should not be disturbed by tilling at any time. Fern roots are fine, fibrous, and close to the surface. Tilling the soil to mix in the fertilizer may easily damage the roots. This means that even with a thin even application and adequate watering, some of the fertilizer may remain on the soil surface. This should not be of consequence, as long as it is of the low burn or no burn type and is not concentrated in one spot. In time these particles will dissolve and reach the roots. Liquid applications have an advantage in that most of the fertilizer salts are dissolved before application and are promptly carried to the roots. However, any solution passing beyond the root zone is lost to the plant. Liquid fertilizers leave less residue in the soil than dry ones do. This is a disadvantage because more frequent fertilization is needed with liquid types. On the other hand, liquid fertilizer may be applied at the time of watering, which saves considerable labor.

HOW FREQUENTLY SHOULD FERNS BE FERTILIZED?—Manufacturers usually have their own recommendations. On the average, one application about every three weeks for liquid forms and at longer intervals for dry application is sufficient. Ferns which do not enter any noticeable rest period, but continue to grow actively the year around, benefit from fertilizers the year around. Ferns which are inclined toward a rest period or dormancy should not be fertilized during this time, as there is little intake of nutrients during periods of inactivity. When not fertilizing, less water is applied, which is beneficial because many tender species of ferns growing in marginal low temperatures are particularly sensitive to overwatering during periods of inactive growth. In very porous soils or under heavy and frequent watering leaching causes a great loss of fertilizer from the soil. On the other hand, soils which do not drain readily retain more fertilizer and need not be fertilized so frequently.

WHAT CAN BE DONE FOR WILTED OR SCORCHED FRONDS?—This kind of damage is difficult to correct with young ferns and those lacking large fleshy rhizomes. As soon as there is any indication of wilting or burning, remove all fertilizer that might be on the surface, see that the plant is well drained, and then water copiously to leach any remaining fertilizer out of the root region. After this liberal watering, water only sparingly so that the soil is aerated and not waterlogged, which will help to reduce the growth of decay organisms on the damaged root hairs and smaller roots. Also increase the humidity of the air and remove badly burned or wilted foliage. Recovery of the plant usually depends on the remaining undamaged roots or rhizomes which may send out new root branches and root hairs. Ferns with large fleshy rhizomes recover more easily because much food and water is stored in the rhizome.

WHAT ELEMENTS DO FERNS SEEM TO NEED MOST?—Nitrogen is the element most needed by plants. It is usually taken into the plant in the form of nitrates, which are very soluble and leach readily from the soil. Plants which have abundant nitrogen respond by producing large, soft, dark green fronds, which though attractive to some gardeners, are not firm and may appear coarse in habit. They are also more easily damaged by wind or during watering. Fewer fertile fronds are also produced. Potassium deficiency is rare, but has been reported for maidenhair ferns (*Adiantum*). The fronds are said to turn an abnormal reddish-brown color. A specific treatment is to apply potassium sulfate at the rate of 1 teaspoon per 9 by 4 inch container. However, using a complete fertilizer should correct and prevent this problem. Trace elements and fern needs are not known precisely. Chelated iron compounds often added to fertilizers are reported to improve color and growth of the Holly fern (*Cyrtomium falcatum*). There are usually enough impurities in fertilizers to take care of the trace element needs of ferns.

WHAT IS SALT INJURY?—In areas of low rainfall the water supply may contain salts which retard plant growth or cause an unsatisfactory soil structure. If these salts accumulate in the soil around roots, stunted growth, scorching of the fronds, and wilting may occur. A white crust of salt may be evident on the surface of the soil or flower pot. In many of the western states it is important to have soil mixes which drain well and thus aid in leaching out the undesirable salts. Thorough watering leaches the soil better than frequent, light watering. Fertilizers containing sodium (e.g., sodium nitrate) should not be used if salt injury is a problem. Additional information may be found in the chapter "Irrigation Water and Saline and Alkali Soils" in the Yearbook of Agriculture (1955), published by the U.S. Department of Agriculture.

Because there are so many physiological, chemical, and physical factors entering into the relationship between growth and fertilization, it is impossible to cover every facet and discuss many of the exceptions. If proper fertilization does not bring about any improvement in a declining plant, one certainly should look for other common causes of poor growth, such as under- or overwatering, poor drainage and aeration, low temperatures, low humidity, inadequate light, and salt accumulation.

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The Valid Varieties of Pellaea andromedaefolia

THOMAS R. PRAY[1]

Since *Pellaea andromedaefolia* (Kaulf.) Fée was first described in 1824, various forms of this Californian species have received systematic recognition. In a monographic revision of section *Pellaea*, to which the species belongs, Tryon (1957, p. 179) regarded none of these variants as taxonomically significant. Certainly anyone familiar with this species in the field, where it grows under a variety of conditions, will recognize the plasticity of the species in response to its environment. Variety *rubens* D.C. Eaton and var. *gracilis* Summers ex Farlow undoubtedly are examples of simple, environmentally induced variants. Regarding the possible significance of other variant forms of *P. andromedaefolia*, some observations concerning a dwarfed specimen are in order. This specimen (*Whitehead 5050*) is quite fertile and is apparently a mature individual. Its leaves are fully tripinnate and it agrees with var. *andromedaefolia* in other respects. The leaves are only 16 cm high however, and the segments are very small, averaging only 4 mm long, compared to the usual 7–10 mm. In spite of its size, young sporophytes raised from its sexual gametophytes were all typical of var. *andromedaefolia* and showed no trace of the diminutive features of the parent plant. Thus, unusually small size, in this case at least, was environmentally induced and not genetically fixed.

On the other hand, var. *pubescens* D.C. Eaton is decidedly distinct. The distinction between this variety and typical *P. andromedaefolia* is the subject of this paper.

Most local floras have ignored the pubescent form of *P. andromedaefolia*. The most recent, that of Munz (1959), mentioned it as occurring in the vicinity of San Diego. Tryon (1957, p. 182) recognized that the pubescent form was from the southern portion of the species' range and stated that it was distinguished by having 32-spored sporangia. The typical glabrous form was said to be

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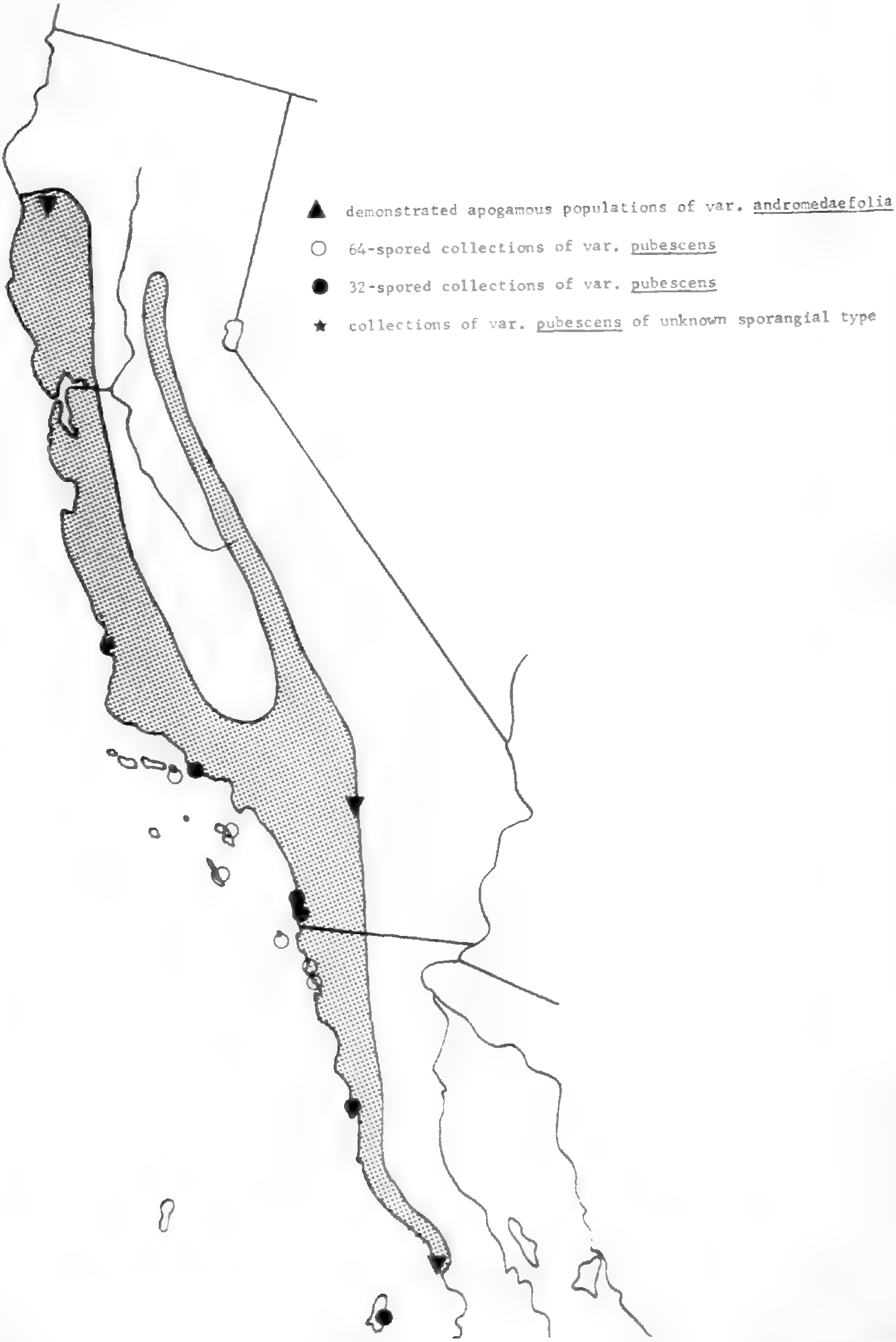
[1] The financial support of the National Science Foundation (Grant #GB-1716) is gratefully acknowledged.

64-spored. The implication was, therefore, that var. *pubescens* was an apogamous form of a sexual species, although at that time there was no direct evidence of apogamy. As the result of extensive field studies, transplant experiments, and the raising of numerous plants from spores, I have found that these statements represent a great oversimplification of the situation.

Plate 7 illustrates the distribution of the species (see *Table I* for a full list of the collections cited in this study). Variety *andromedaefolia*, with glabrous stipes and rachises and glaucous leaf segments, ranges from northern California—a report from southern Oregon is doubtful, as stated by Tryon (1957, p. 182)—southward through the state and along the west coast of Baja California Norte, Mexico, to the region of Bahia de Sebastian Vizcaino. In central California it extends inland to the foothills of the Sierra Nevada and in southern California it occurs along the western borders of the Colorado Desert. In the southern part of its range it occurs on some of the offshore islands. While var. *andromedaefolia* was well distributed at one time on Santa Catalina Island, only a single collection has been made in recent years (*McNeil 76*). Much searching in appropriate habitats has revealed that it is now extinct there, or nearly so. Similarly, three days of searching on Santa Cruz Island produced a single specimen of the typical variety on an inaccessible cliff where it could not be collected.

Variety *pubescens*, with puberulent stipes and rachises and non-glaucous segments, occurs from San Luis Obispo south to Cedros Island. It appears to be a strictly coastal ecotype, a fact which has not been recognized previously. All the material I have seen is from coastal bluffs and hills and at or near the mouths of coastal canyons. The type of var. *pubescens* came from the San Luis Obispo area (Eaton, 1878). Its occurrence there has been recently confirmed (Hoover, 1966). I have not seen any material from this most northern locality, but Hoover's comments suggest that his material is the same as that which I have studied. The most northern collections available to me came from southern Ventura County (Point Mugu). I know of no locality between this and San Luis Obispo, although suitable habitats in



Map of the Distribution of P. andromedaefolia. Shaded area indicates the general distribution of var. pubescens and var. andromedaefolia in California and Mexico.

the intervening regions have been searched carefully. Although the coastal area between Point Mugu and Los Angeles seems a likely habitat, I know of no collections of var. *pubescens* from there. It does occur to the south in San Diego County, where I have made several collections. On the offshore islands the presence of var. *pubescens* is definitely established for Anacapa, San Clemente, South Coronado and Cedros Islands. It may also have occurred on Santa Catalina, but several personal attempts to find extant material of this variety were unsuccessful. The floras of these islands have been decimated by overgrazing of sheep, or goats, or both to such an extent that it is no longer possible to find many species where they were once collected. For Mexico, I have seen material from Ensenada south to San Quintín.

From the relatively small amount of material studied it would appear that the two varieties do not usually occur in the same locality. The typical form is rarely found in the exposed maritime environment to which var. *pubescens* is largely restricted. The only instance of sympatry observed was at Point Mugu, where there were a few, very small individuals (*2028*) of the typical variety in a population predominantly of the pubescent variety.

D. C. Eaton (1878) distinguished var. *pubescens* only by the presence of the fine pubescence on the stipes and rachises and cited a specimen from San Luis Obispo (*Mrs. R. W. Summers*). Apparently neither he nor anyone since has noticed that, although the pubescence provides one obviously distinguishing feature (clearly visible only when magnified), several others are equally obvious. In life the pinnules of var. *pubescens* are succulent and are bright green and shiny on the upper surfaces. Upon drying the upper surface looks resinous. The segments appear to be thicker than those of the typical variety; sections of the pinnules did not confirm this, however. On the other hand, the pinnules of var. *andromedaefolia* are consistently at least slightly glaucous and dull. The development of anthocyanins in the leaves as a response to drought or extreme exposure is common to both forms. The vein pattern is clearly evident on the upper surfaces of the pinnules in fresh condition in var. *pubescens*, whereas this feature is obscure

TABLE I. LIST OF COLLECTIONS[1]

Coll. number	*Locality*	*Sporangial type*
	VARIETY ANDROMEDAEFOLIA	
1668	Santo Tomas, highway #1 at Km 193, Baja Calif. Norte, Mex.	64-spored
1669	San Juan Canyon, Orange Co., Cal.	64-spored
1909	Andreas Canyon, Palm Springs, Riverside Co., Cal.	32-spored
2028	Point Mugu, Ventura Co., Cal.	64-spored
Dunkle 1881	Santa Catalina Isl.	64-spored
Dunkle 2865a	Santa Catalina Isl.	64-spored
Garth 1089	Andreas Canyon, Palm Springs, Riverside Co., Cal.	32-spored
McNeil 76	Holland's Cove, Santa Catalina Isl.	Immature
J. H. Thomas 8223 (DS)	Miller's Landing, Baja Cal. Norte, Mex.	32-spored
Tryon & Tryon 5556 (GH)	Redway, Humboldt Co., Cal.	32-spored
Wiggins 9967 (DS)	40 mi. NE of El Rosario, Baja Cal. Norte, Mex.	64-spored
Whitehead 5050	no data	64-spored
	VARIETY PUBESCENS	
1665, 1666	Ensenada, S on highway #1 at Km 66, Baja Cal. Norte, Mex.	64-spored
1667	as above at Km 81	64-spored
1906, 1907, 2027	Point Mugu, Ventura Co., Cal.	32-spored
2056, 2057	Del Mar, San Diego Co., Cal.	32-spored
3215	grown from spores of 1665	—
Cooper 2172	Ensenada, Baja Cal. Norte, Mex.	—
Dunkle 2043	Little Gibraltar, Santa Catalina Isl.	64-spored
Dunkle 4262	Johnson's Trough, Baja Calif. Norte, Mex.	—
Dunkle 7663	Anacapa Isl.	64-spored
Elmore 383, 413	San Clemente Isl.	64-spored
Epling & Stewart (DS)	San Quintín, Baja Cal. Norte, Mex.	32-spored
Ferris 8511 (DS)	San Vicente, Baja Cal. Norte, Mex.	Immature
Moran 8301	South Coronado Isl., Mex.	64-spored
Moran 1065 (DS)	Cedros Island, Mex.	Immature

Coll. number	*Locality*	*Sporangial type*
UCBG 62.432-1	Cultivated. Original from San Diego Co., Cal. (*Hutchison 2160*)	32-spored
Wiggins 11974 (DS)	South Coronado Isl., Mex.	Immature

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[1] All collections of var. *pubescens* seen are included. Only those of var. *andromedaefolia* especially pertinent are cited; many others have been examined. Collection numbers not otherwise identified are those of the author. Specimens are deposited in the herbarium of the Allan Hancock Foundation (AHFH), University of Southern California, unless indicated otherwise.

in the typical variety. Unfortunately, this characteristic sometimes becomes less evident in drying. The degree of lamina dissection is most useful in mature plants. The leaves of the typical variety are usually tripinnate (rarely quadripinnate), even in rather depauperate specimens. Variety *pubescens*, in contrast, has bipinnate leaves, even in the largest plants. The largest leaves may have a very few ternate pinnules in the basal pinnae. In the typical variety many of the pinnules commonly have 5–7 (occasionally up to 10) segments; pinnules even in the upper portion of the leaf are usually at least ternate. Correlated with the simpler leaves of var. *pubescens* is the increased size of the ultimate segments. This distinction is well demonstrated when the two varieties are cultivated under similar circumstances, but segment size varies with environmental conditions, so herbarium material can not be reliably distinguished on this basis. The stature of the two varieties also distinguishes them. Under the best conditions the typical form may produce leaves as much as 80 cm long. The largest specimens of var. *pubescens* studied had leaves only 35 cm long, and most specimens were much smaller. No cultivated material has been observed to exceed this height. The stouter and more rigid stipes and rachises are correlated with the shorter stature.

Among the distinctive features of var. *pubescens*, the nonglaucous segments and bipinnate leaves can be used to identify it, even if it is not pubescent. One collection from Santa Catalina Island (*Dunkle 2043*) has all of the characteristics of var. *pubescens* except pubescence. The collection consists of several old leaves only, and it is possible that this latter feature has been lost with age. An effort was made to recollect this fern from the Dunkle locality, but no plants of either variety were found. This specimen is the only evidence I found for var. *pubescens* on Santa Catalina. A collection from Anacapa Island (*Dunkle 7663*) also lacks the puberulence typical of var. *pubescens*, but is otherwise indistinguishable from material of this variety. Tentatively, therefore, it is listed as var. *pubescens*. Perhaps these two collections are hybrids of the two varieties. It should be noted that the insular collections of var. *andromedaefolia* do tend to be smaller plants with less complex leaves than is typical for the variety. Whether these represent local variants cannot be decided on the basis of the meager material available.

Under cultivation the differences between these two varieties were maintained and were especially obvious when the plants were compared side by side. Both varieties were also grown to maturity from spores, and the progeny retained the distinguishing features of the parents. No intermediates have been discovered in the field. At Point Mugu, the only locality where the two varieties were observed growing together, the plants of var. *pubescens* were apogamous, whereas the plants of var. *andromedaefolia* were 64-spored and presumably had sexual gametophytes. Therefore, the lack of intermediates between the varieties is understandable.

Tryon (1957) reported that the pubescent form is 32-spored, but further study has shown that no such correlation between spore number and morphology exists. The material from Point Mugu (*1906*, *1907*) is 32-spored and reproduces by apogamy (Pray, ms.). Material from San Diego County also is 32-spored and apogamous (*2056*, *2057*, *UCBG 62.432-1*.) In contrast, the plants on the islands that are directly offshore from these localities apparently are sexual. Among the insular collections cited, some were too immature to determine their spore number and probable reproductive method. Only *Elmore 383* and *413* from San Clemente and *Dunkle 7663* from Anacapa had spores; these are all 64-spored. Collections from northern Baja California (*1665*, *1666*, *1667*) and adjacent South Coronado Island (*Moran 8301*) are 64-spored and produce sexual gametophytes. The southernmost collection, from San Quintín (*Epling & Stewart*), is probably 32-spored, although a positive count could not be made. Tryon (1957) reported a Cedros Island collection to be 32-spored. The distribution pattern for apogamy in var. *pubescens* based on available material is puzzling (*Plate 7*). If the present pattern can be taken as a reflection of the history of this variety, then perhaps var. *pubescens* had its origin in northern Baja California from whence it spread to the Coronado and Channel Islands. On the mainland it may have moved both north and south through the formation of apogamous races which apparently reached the islands only in the south.

Although most collections of var. *andromedaefolia* are 64-spored (and those investigated produced sexual gametophytes), 32-spored and apogamous individuals are scattered throughout the range of this variety: Humboldt County (*Tryon & Tryon 5556*), Sierra Nevada foothills near Yosemite, (Tryon, pers. comm.), Palm Springs (*1909, Garth 1089*), and Baja California (*Thomas 8223*, which is the most southerly record for the typical variety). All other determinable Mexican collections are 64-spored. All the insular material for which a spore count is available is 64-spored. Thus, in the typical variety apogamy is sporadic; it seems likely that each of the apogamous populations has had a separate origin. Differences among the gametophytes from each of those that has been investigated support this assumption (Pray, 1968).

There does not appear to be any correlation between morphology and spore number in either variety. The only method by which apogamous populations can be identified is by spore count. This contrasts with the closely related *P. ovata,* which also has both 64- and 32-spored forms. All of the material of *P. ovata* studied thus far has shown that the 64-spored plants are glabrous and produce sexual gametophytes, whereas the 32-spored plants all show varying degrees of pubescence. All of the latter type that have been tested have produced apogamous gametophytes.

It is clear that the differences between var. *andromedaefolia* and var. *pubescens,* which are summarized in *Table II*, are sufficiently marked to merit the systematic recognition of var. *pubescens*. In my opinion, the two varieties are comparable to good subspecies in other groups. To a very remarkable degree the situation in *P. andromedaefolia* parallels a similar situation in another Californian species, *P. mucronata* (D. C. Eaton) D. C. Eaton. The general distribution pattern of the two species is very similar (Tryon, 1957), and in fact they are often in the same localities; in these *P. mucronata* will be found in drier, more exposed habitats. *Pellaea mucronata* is represented throughout most of its range by the common form, var. *mucronata*, characterized by finely divided, tripinnate (rarely quadripinnate) leaves. In the higher mountains of central and southern California the typical variety is replaced by a montane ecotype, var. *californica* (Lemmon) Munz & Johnston, which differs in its smaller stature and in its bipinnate and more compact leaves. Thus, both of these fairly widespread species appear to have evolved specialized and reduced ecotypes to fit more extreme environments, in one case the maritime environment, in the other the montane.

TABLE II. COMPARISON OF THE TWO VARIETIES OF P. ANDROMEDAEFOLIA

Character	*Variety andromedaefolia*	*Variety pubescens*
Range	cismontane & insular Calif.; western Baja Calif. Norte, Mex.	coastal & insular So. Calif.; adjacent Mex. to Cedros Island
Sporangial type	64-spored; sporadic 32-spored populations	64-spored Channel Isls. and northern Baja Calif. Norte; 32-spored, southern Baja Calif. Norte, Mex., Cedros Isl. and southern Calif.
Height	up to 80 cm	less than 35 cm
Leaf form	tripinnate, many pinnules with 5–7 segments	bipinnate, a few ternate pinnules; ultimate segments usually larger
Stipe & rachis	glabrous, slender	puberulent, stouter
Leaf color	dull, glaucous	shiny, bright green
Venation	evident on lower surfaces only	prominent also on upper surfaces, especially in living state

The parallel may be extended even further, for each of these species also has a counterpart species in the southwestern region of the interior of the continent. Here *Pellaea longimucronata* replaces *P. mucronata*. Their relationship is sufficiently close to permit hybridization at points of contact (Pray, 1967). In the same region *P. intermedia* replaces *P. andromedaefolia*. In this case there is a considerable gap between the ranges of the two species. In spite of the remarkable similarity between *P. intermedia* and *P. andromedaefolia* var. *pubescens* it seems unlikely that there is a direct relationship because of the specialized ecology of the latter. More probably, these two are parallel developments and, if closely related, it is through var. *andromedaefolia*. Nevertheless, if the geographic origin of herbarium specimens of var. *pubescens* were not known, these would be easily confused with *P. intermedia*, which is also characterized by bipinnate leaves with puberulent stipes and rachises. Probably the simplest method by which they may be distinguished, as indicated in Tryon's key (1957), is the very clear vein pattern evident on the underside of the segments of *P. andromedaefolia* in contrast to the unveined appearance of *P. intermedia*. When compared closely, the rhizome scales are also distinctive, although they are of the same general type. Those of *P. andromedaefolia* var. *pubescens* are about twice as broad at the base and appear lighter when the rhizome is viewed with a hand lens. The dark central band extends about ½ to ⅔ the length of the scale, whereas in *P. intermedia* the central band extends to the scale tip. The clear margins of the scale seem a bit broader in var. *pubescens*, but the difference in this respect is not obvious.

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Petiolar Shoots in the Dennstaedtioid and Related Ferns[1]

JUDITH E. TROOP AND JOHN T. MICKEL

Stelar branching patterns and bud formation in the Filicales have been investigated little since the beginning of this century. Fern stems may branch by dichotomy, axillary buds, or buds not clearly in the axils of leaves. Buds from frond bases were reported and described by Gwynne-Vaughan (1903) for a number of ferns. In a monographic work on *Dennstaedtia punctilobula* (Michx.) Moore, Conard (1908) described in detail the anatomy of shoots from the petiole bases of this fern. Webster (1958) observed dormant buds on the leaf bases in *Pteridium aquilinum* var. *latiusculum*, but none were seen to elongate. Further references to budding of ferns are scattered, and the phenomenon is mentioned only briefly, as in Wardlaw (1952) and Wagner (1963), for *Matteuccia*, *Onoclea* and *Dryopteris*. None of these workers has attributed any phylogenetic or taxonomic importance to the phenomenon, and, in view of the meager information available, it is appropriate that more comprehensive studies be undertaken.

In the summer of 1967 we participated in a course in the biology of tropical pteridophytes offered by the Organization for

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[1] This study was done while the senior author held a National Defense Education Act Fellowship. Partial cost of publication of this paper was borne by the Smithsonian Institution while the junior author was a National Research Council Visiting Research Associate in the Department of Botany of the Smithsonian Institution.

Tropical Studies in Costa Rica (Mickel, 1967), in which we had the opportunity to investigate a great diversity of fern genera and species in regard to their branching patterns. This study is based upon free-hand sections of rhizomes and petiole bases examined under a dissecting microscope. The results show that the phenomenon of petiolar branching occurs more commonly in the ferns than was thought previously (*Table I*). This branching is very widespread in the dennstaedtioid ferns, being a nearly constant feature in *Dennstaedtia*, *Hypolepis*, *Paesia*, and *Histiopteris*, less constant in *Pteris*, and absent in *Saccoloma*. Also in the Cyatheaceae petiole branches are always present in *Lophosoria* and *Cyathea mexicana*, and occasionally so in *Dicksonia* and *Metaxya*. One species of *Dicksonia* studied had up to six buds on the lower stipe. *Metaxya* is reported (Bower, 1928) to bud from the petiole base, but our specimen did not.

In most of the ferns studied, the vascular strand to the frond begins as a bulging of the rhizome stele (*Figs. 1* and *3*), followed by its breaking away from the stele and passing out through the cortex. In all the ferns studied the frond trace retains a basic horseshoe shape with the additions of hooks, corrugations, and dissections in various species. The gap left in the rhizome stele by the departing frond is then closed. The rhizomes of some species possess a dicyclic (or rarely tricyclic) solenostele. In these plants the closure of the frond gap may be accomplished by a portion of the inner stele filling the outer. The whole inner solenostele may migrate to the gap, leave a filling portion, and center again as it closes its own gap (*Fig. 3*); or the section which will fill the outer stele may depart from the inner stele and migrate to the gap (*Fig. 2*). If there is a third solenostele, it repeats the pattern of the second.

The bud develops well up on the stipe, at least after the leaf trace has become well differentiated from the rhizome stele (*Fig. 1*). (One exception to this was in *Cyathea* where the bud develops with the petiole trace but appears superficially to be on the stem to one side of the leaf base.) The adaxial hook of the petiolar strand lengthens laterally and separates from the

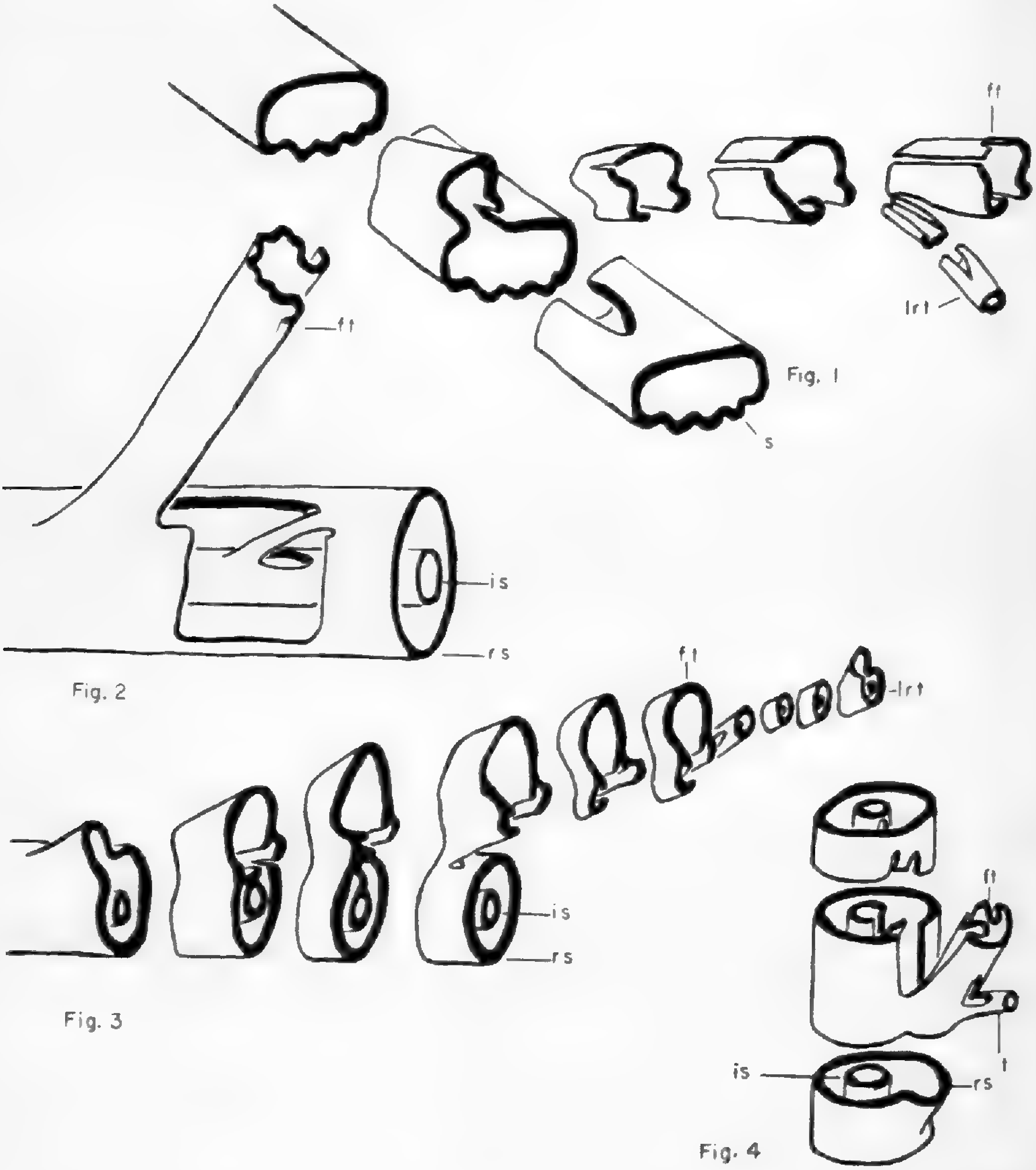

FIG. 1. EXPLODED DIAGRAM OF HYPOLEPIS REPENS STELAR SYSTEM. FIG. 2. SACCOLOMA INAEQUALE STELAR SYSTEM. FIG. 3. EXPLODED DIAGRAM OF DENNSTAEDTIA DISSECTA VASCULAR SYSTEM. FIG. 4. EXPLODED DIAGRAM OF PTERIS ALTISSIMA VASCULAR SYSTEM. The abbreviations are: ft = FROND TRACE, is = INNER RHIZOME STELE, lrt = LATERAL RHIZOME TRACE, rs = OUTER RHIZOME STELE, s = RHIZOME STELE, and t = ABAXIAL PETIOLAR BRANCH.

frond stele, gradually closing into a new solenostele. The frond stele reforms the adaxial hook. In the dicyclic condition the inner stele of the lateral shoot may repeat the ontogeny of that of the main rhizome. This was found in *Pteris* and some species of *Dennstaedtia*. In other dicyclic species, however, the inner stele forms by an invagination of the outer stele, which separates and moves into the center closing into a solenostele (*Fig. 3*).

There are but few generic differences from the above general pattern. The species of *Hypolepis* investigated are fairly uniform in their anatomy with usually dorsiventral rhizomes, unicyclic solenosteles and petiolar branches. There are usually two to four petiolar buds, often well-developed and growing as lateral branches bearing fronds. *Histiopteris incisa* is scarcely distinguishable from *Hypolepis* in its stelar anatomy; the two are closely allied.

All the Dennstaedtias examined bore lateral shoots on the petioles (usually one per petiole), whereas only two species (*D. bipinnata* and *D. cicutaria*) displayed dichotomizing rhizomes. *Dennstaedtia bipinnata* is the only unicyclic species studied. *Dennstaedtia cicutaria* exhibits a most peculiar pattern. The rhizome appears to terminate in a trichotomy consisting of a central petiole and two rhizome branches. Since this type of branching pattern is found in no other species examined and only irregularly in *D. cicutaria*, it seems likely that the rhizome has branched dichotomously while a petiole was produced simultaneously.

Some ferns form buds in positions other than at the adaxial petiole trace hooks. The fronds of both *Pteris podophylla* and *Pteris altissima* produce buds from the abaxial side of the petiole strand (*Fig. 4*). This position also has been found in three species of Costa Rican *Grammitis* (L. E. Bishop, pers. comm.). The bud in *Dicksonia* develops from the lateral vascular arc, and in *Lophosoria* bud formation occurs on the lateral side of the abaxial strand. The bud trace of *Paesia* arises from both adaxial and abaxial portions of the petiole trace, one section from the adaxial hook and two sections from the abaxial corrugated arc. These three strands unite to form the lateral branch. The ability of the petiole trace to form a rhizome stele is not limited to a specific portion of the petiole.

The petiolar branching discussed above resembles that of certain coenopterid ferns of the Carboniferous Age. *Botryopteris* and *Anachoropteris* are well-known examples in which branches often arise from the petioles. Surange (1952) interprets the anatomy of *Botryopteris* as a dorsiventral stem giving rise to a terete stem upon which petioles and roots are borne. Delevoryas and Morgan (1954) discuss the phenomenon of stems arising from

Table I. Rhizome Characteristics in Dennstaedtioid and Related Ferns.

Name	*Stelar cycles*	*Dichotomies*	*Petiolar branches*
Blotiella lindeniana (Hook.) Tryon (*3432*)[1]	1	—	+
Culcita coniifolia (Hook.) Maxon (*3238*)	1	–	–
Cyathea mexicana Schlecht. & Cham.	1	–	+
Dennstaedtia arborescens (Willd.) Ekman ex Maxon (*1870, 2037, 2045, 2212, 2226, 2305, 2526, 2535, 2589, 3111, 3305*)	2	–	+
D. bipinnata (Cav.) Maxon (*2697, 3345, 3505, 3593, 3616*)	1	+	+
D. cicutaria (Swartz) Moore (*1869, 2303, 2914, 3118*)	2	+	+
D. dissecta (Swartz) Moore (*2209, 2210, 2217, 2224, 2301, 2594*)	2	–	+
D. obtusifolia (Willd.) Moore (*1871, 2302, 2304, 2595, 2631*)	2	–	+
D. spinosa Mickel (*2730*)	2	–	+
Dicksonia gigantea Karst. (*3134*)	1	–	+
Histiopteris incisa (Thunb.) J. Smith (*2182, 2483, 3193*)	1	–	+
Hypolepis bogotensis Karst. (*2169, 3248*)	1	–	+
H. nigrescens Hook. (*3422*)	1	–	+
H. nuda Mett. (*3300*)	1	–	+
H. pulcherrima Underw. & Maxon (*3306*)	1	–	+
H. repens (L.) Presl (*1972, 2000, 2306, 2743, 3048*)	1	–	+
H. rigescens (Kunze) Fée (*2457*)	1	–	+
H. viscosa (Karst.) Mett. (*3315*)	1	–	+

Name	*Stelar cycles*	*Dichotomies*	*branches*
Lonchitis hirsuta L. (*2293, 2590, 3557*)	1	–	–
Lophosoria quadripinnata (Gmel.) C.Chr. (*2431*)	1	–	+
Metaxya rostrata (H.B.K.) Presl (*2853*)	1	–	+
Paesia anfractuosa (Christ) C. Chr. (*3000*)	1	–	+
Pteridium aquilinum var. *arachnoideum* (Kaulf.) Herter (*2017, 2153*)	2	+	+
P. a. var. *caudatum* (L.) Sadeb. (*2395*)	2	+	+
Pteris altissima Poir.	2	–	+
P. podophylla Swartz (*3177*)	2–3	–	+
P. pungens Willd. (*3563*)	1	–	–
P. quadriaurita Retz.	1	–	–
Saccoloma elegans Kaulf. (*1932, 2799*)	2	–	–
S. inaequale (Kunze) Mett. *1992, 2755, 3128, 3566*)	2	–	–

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[1] The numbers cited are Mickel collection numbers. Voucher specimens are deposited at US, ISC, LP, and USJ. Those without vouchers cited were common species not collected at the time of the study.

petioles, particularly in *Anachoropteris clavata*. They believe that Surange's "dorsiventral stem" is actually a petiole with stems arising from it as in *Anachoropteris*. *Anachoropteris clavata* is postulated as a scrambling plant with some petioles functioning as stolons producing new stems. Other coenopterid ferns are also known to have branching petioles (T. Phillips, pers. comm.).

Among the modern dennstaedtioid ferns several have a habit similar to the above. In *Hypolepis*, for example, the petioles are not entirely erect from the rhizome, but creep for a distance before becoming erect. This horizontal portion bears the branch shoots and closely approximates the condition described by Delevoryas and Morgan. Thus, the patterns of branching and bud formation in these ferns are perhaps more significant than previously believed, for questions are raised regarding the relation of the frond to the rhizome, the basic ontogeny of the frond, and the phylogeny of the dennstaedtioid ferns. Further work on these problems is currently in progress.

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Marsilea maheshwarii, a New Species from Pondichery, India

BRIJ GOPAL

The genus *Marsilea* is represented in India by nine species,[1] most of which are restricted in distribution, *M. minuta* L. being the only species found throughout India. Endemism is of common occurrence throughout the genus. While examining collections of *Marsilea* from all over the country, I found that some collections

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[1] Gupta, K. M. 1962. Marsilea. Botanical Monograph no. 2, C. S. I. R., New Delhi, India.

from Pondichery represented a new species, which is here named in honor of the late Professor P. Maheshwari.

MARSILEA **maheshwarii** Gopal, sp. nov.

Plantae aquaticae; rhizomata robusta, apice pubescentia; petioli longi; lamina lata, marginibus integris; sporocarpia aggregata 3 vel 4, interdum 2, petiolo adnata 2–5 mm a basi; pedicelli connati et ramosi, penitus adnati sporocarpio, eique aequilongi vel eo paulo longiores; sporocarpia 3.5–4.0 × 3.0–3.5 mm, lateraliter compressa, rotundata in fronte, horizontalia vel deorsum flexa; cornua bina, distincta, inferius quidem minutum et obtusum, superius vero longum et recurvum; sori 12–16; megasporae nullae vel aberrantes; microsporae aberrantes.

TYPE: Pondichery, India, from the paddy fields, *G. Thanikaimoni 992a* (Herbarium of the French Institute, Pondichery, CAL).

PARATYPES: *loc. cit.*, *G. Thanikaimoni 992b* (US), *992c* (K), *992d* (BAN).

Marsilea is well known for its morphological plasticity. For example, it is very difficult to distinguish between species growing submersed. However, the characters of the sporocarp are more stable and have largely been used in specific identifications. *Marsilea maheshwarii* is recognized mainly on the basis of sporocarp characters. Gupta (*loc. cit.*) recognized three groups in the genus which differ in the mode of attachment of the pedicel to the petiole. The *Quadrifolia* group is characterized by pedicels that are adnate to the petiole at one point, and until now has been represented in India only by *M. quadrifolia*, known from Kashmir alone. *Marsilea maheshwarii* from Pondichery has a similar attachment, which excludes any possibility of its being one of the *Minuta* group (like *M. minuta* or *M. coromandelica* Burm. f.), in which the sporocarps are always basal. The Pondichery material differs widely enough from *M. quadrifolia* to warrant its recognition as a new species.

Among the various characters, the mode of attachment of pedicel to pedicel, pedicel to sporocarp, and the shape of sporocarps in the two species are quite different (*Figs. 1, 2*). In addition, the shape of the horns, the aberrant microspores, and the usual absence of megaspores (aberrant if present) also contrast with

TABLE I. MORPHOLOGICAL FEATURES OF SPOROCARPS OF M. MAHESHWARII AND M. QUADRIFOLIA

Characters	*M. maheshwarii*	*M. quadrifolia*
Sporocarp number	3 or 4, sometimes 2	2 or 3, rarely solitary
Relation of pedicel to petiole	adnate, 2–5 mm above petiole base	adnate
Relation of pedicel to pedicel	connate ⅓–½ their length	connate ca. ½ their length, sometimes only at base
Shape and length of sporocarp	bean-shaped, compressed, not margined, not ribbed, 3.5–4 mm	oval, subcompressed, rarely margined, not ribbed, 5–6 mm
Pedicel disposition	obliquely ascending	decurved or somewhat ascending
Pedicel : sporocarp ratio	1 : 1 to 1.5 : 1	2 : 1, sometimes up to 3 : 1
Sporocarp surface	densely hairy, glabrate at maturity	strigose
Relation of pedicel to sporocarp	fully adnate	adnate
Number and nature of horns	2, lower small and blunt, upper long and recurved, sometimes broken at maturity	2, almost similar
Number of sori	12–16	16–20
Sporocarp contents	microspores aberrant, megaspores absent or aberrant	normal

M. quadrifolia. Vegetative characters were compared in the two species and also in *M. minuta* grown under exactly identical conditions (both submersed and dry). *Marsilea maheshwarii* is a stouter species than the other two. The leaflet margins remain almost entire under all conditions of moisture in *M. maheshwarii*, but they become crenate in the other species under dry conditions. The various characters of the two species are listed in *Table I*.

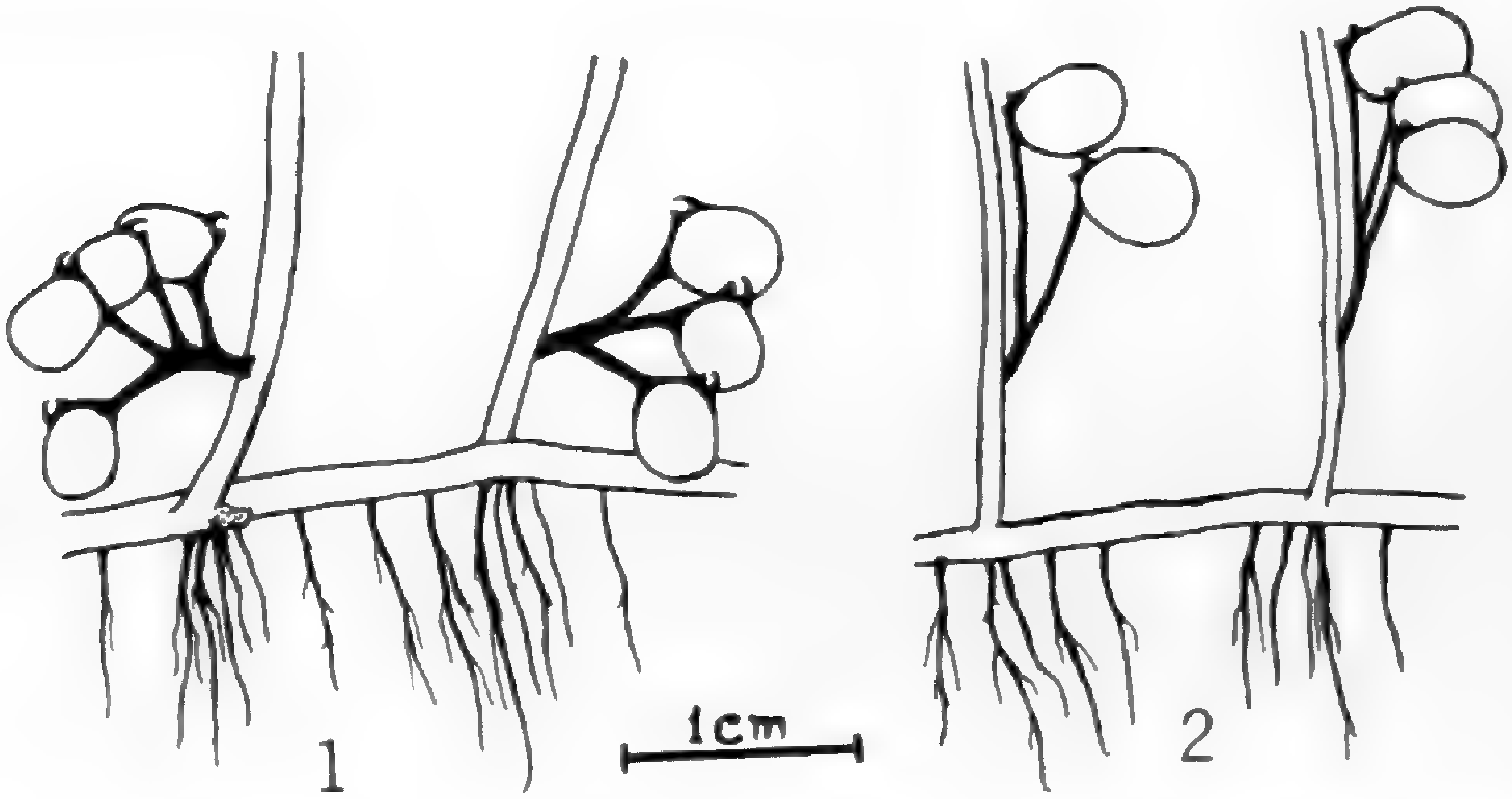

FIG. 1. PORTION OF A RHIZOME OF MARSILEA MAHESHWARII SHOWING DISPOSITION OF SPOROCARPS. FIG. 2. SAME, M. QUADRIFOLIA.

I am very much indebted to Mr. G. Thanikaimoni of the French Institute, Pondichery, India, for his valuable help in collecting the material for my study, and to Rev. Fr. H. Santapau, Director, Botanical Survey of India, Calcutta, for kindly providing the Latin translation of the description. Thanks are also due Prof. R. Misra and Dr. K. C. Misra of the Botany Department, Banaras Hindu University, for encouragement and facilities accorded me.

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Phloem Studies in the Pteridophytes, Part I. Equisetum.

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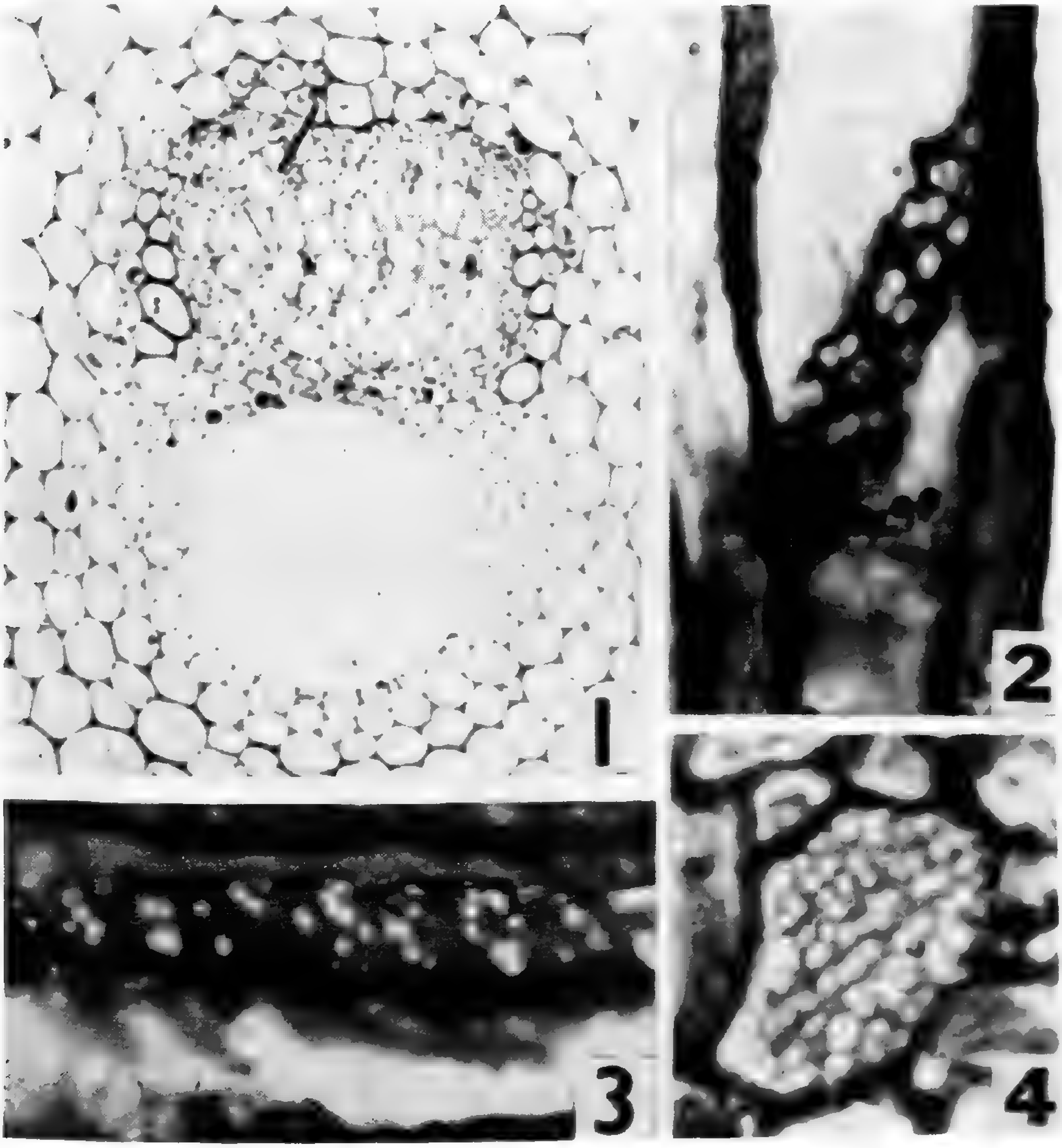
Xylary tissues of the pteridophytes have been studied in detail by several workers, but phloem tissue has received very little attention. The probable reason for this is the difficulties encountered in studying the anatomical structure of the phloem, for example in cutting perfect radial longitudinal and cross sections of sieve elements showing the details of sieve areas and in staining the tissues.

Little is known about the phloem anatomy of *Equisetum*. I have studied phloem in the rhizomes and aerial shoots of *E. hyemale*, *E. telmateia*, *E. arvense*, and *E. giganteum*. This paper concerns only the latter two species. The purpose of this investigation was to gather data on *Equisetum* phloem that could be compared with presumably comparable tissue described in some American calamites (Agashe, 1964).

Johnson (1933), in discussing the origin and development of certain tissues in *E. scirpoides*, mentioned the occurrence of sieve plates with small pores on the lateral walls of the sieve cells. Golub and Wetmore (1948) described the development of phloem in *E. arvense*. According to them, protophloem sieve cells may be 3 mm long or more. Their longitudinal walls have many, transversely elliptical, faintly staining sieve areas; such areas are also found on the oblique end walls, but they do not seem to form distinct sieve plates. Metaphloem sieve cells are longer, larger in diameter, and have densely granular cytoplasm and very thick walls; sieve areas are more common on the end wall in metaphloem than in protophloem.

There appears to be some confusion in the literature regarding the definitions of sieve cells and sieve tubes. The presently accepted definitions, according to Esau, Cheadle, and Gifford (1953), who quote Cheadle and Whitford, state that a sieve tube consists of sieve elements joined end-to-end to form a vertical tube-like structure in which sieve areas are more highly specialized on the



Stem Phloem in Equisetum. Fig. 1. Transverse section of E. giganteum showing one vascular bundle, × 160. Fig. 2. Radial longitudinal section of a sieve tube of E. giganteum showing portion of a sieve plate on an oblique end wall, × 910. Fig. 3. Radial longitudinal section of a sieve tube of E. arvense showing sieve areas on lateral walls, × 1385. Fig. 4. Transverse section of E. arvense showing a single sieve tube with a sieve plate on an end wall, × 915.

end walls than on the lateral ones. Sieve cells are not joined vertically to each other and have sieve areas on both lateral and end walls which are of similar specialization.

In order to secure perfect radial longitudinal sections of phloem tissue, stem material was split lengthwise and a small piece containing only two or three vascular bundles was selected. This material was soaked in hydrofluoric acid to soften it before embedding it in paraffin. Harris' Haematoxylin was the most suitable stain for sieve elements.

As shown in the cross section of a portion of an aerial shoot of *E. giganteum* (*Fig. 1*), the phloem tissue consists of several cells of two types, and is flanked on either side by radial xylem strands. Just below the phloem is a large protoxylary canal. The whole vascular bundle including the protoxylary canal is surrounded by an individual endodermis marked by a Casparian strip on the lateral walls. Inside the endodermal layer is a single-celled layer of pericycle. The phloem tissue is composed of large sieve tubes and small parenchymatous cells. As shown in the radial longitudinal section of a sieve tube (*Fig. 2*), the end wall is oblique. However, in some sieve tubes the end wall is transverse. Most of the sieve tubes are 30 μ in diameter and 430 μ long. Sieve areas are scattered over the radial walls and include one to three pores. The pores in the oblique end wall sieve plate are 4–5 μ in diameter, whereas most of the pores in the radial walls are 2 μ in diameter.

The most clearly defined sieve plates and sieve areas were observed in the end walls (*Fig. 4*) and radial walls (*Fig. 3*) of the sieve tubes of *E. arvense*, features which have not been illustrated clearly in previous accounts. The sieve areas on the radial walls consist of many pores. In some sieve plates on end walls cytoplasmic strands in the pores can be seen. There seems to be some deposition of callus on the sieve plates.

It can be concluded that the phloem in these species of *Equisetum* is fairly advanced among the pteridophytes because of the presence of sieve tubes and not sieve cells. I am grateful to Prof. Henry N. Andrews for his advice and encouragement and to Mr. S. K. Sutar for his help in preparing the photographs.

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A New Genus of Salviniaceae and a New Species of Azolla from the late Cretaceous[1]

John W. Hall

The Salviniaceae are represented in the Cretaceous by two species of *Azolla* recently described from North America. *Azolla cretacea* Stanley is based on massulae; it has been reported from the Hell Creek Formation of South Dakota (Stanley, 1965), Montana (Norton and Hall, 1967) and the time-equivalent Edmonton Formation of Alberta (Srivastava, 1966). *Azolla geneseana* Hills and Weiner is known both as massulae and megaspores from the Edmonton Formation in Alberta (Hills and Weiner, 1965).

These few reports are scarcely indicative of the place of the family in the Cretaceous, at least in the fluviatile deposits of eastern Montana that I have looked at. By using the simple sieving and sorting techniques customarily used for isolating megaspores from sediments, large numbers of massulae and megaspores of *Azolla* have been found. They are so abundant and heterogeneous as to suggest that the family was not only a conspicuous component of the aquatic vegetation, but was morphologically

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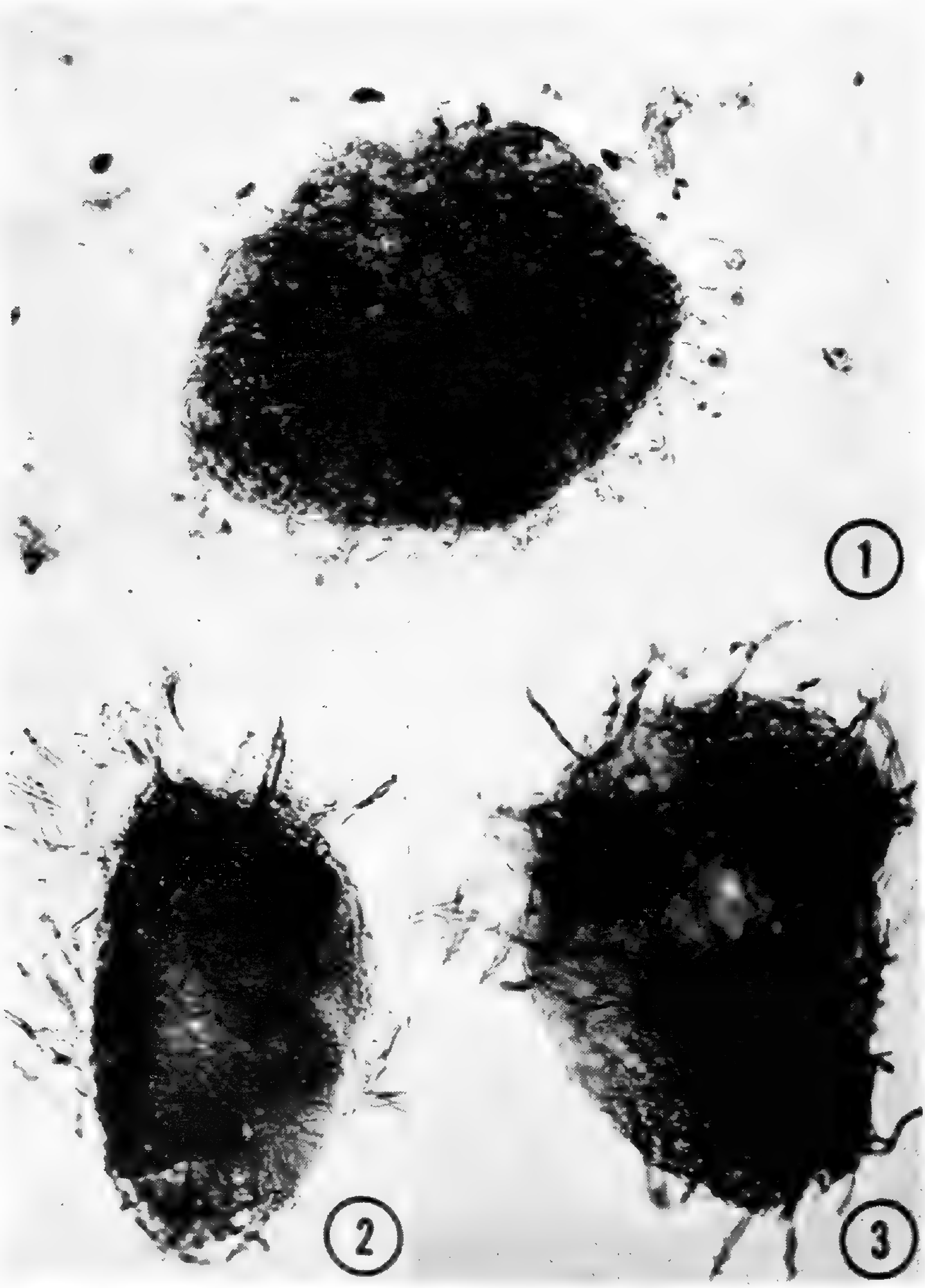


FIG. 1. HOLOTYPE OF AZOLLA CIRCINATA, × 325. FIGS. 2 AND 3. MASSULAE FROM THE PARATYPE OF AZOLLOPSIS TOMENTOSA, ×175.

more diverse then than it has been subsequently. One new genus, with both megaspores and massulae, and a new species of *Azolla* representing what I consider to be a new section of the genus are described here.

Among the extant species of *Azolla*, as well as the previously described fossils, there are two types of massulae. Section *Azolla* accomodates those species whose massulae have anchor-shaped glochidia; in sect. *Rhizosperma* the massulae lack glochidia. Section *Azolla* dates from the Cretaceous and sect. *Rhizosperma* from the Oligocene. The massulae of the species of *Azolla* described here possess glochidia that are filamentous and coiled.

AZOLLA sect. **Filifera** J. W. Hall, sect. nov.

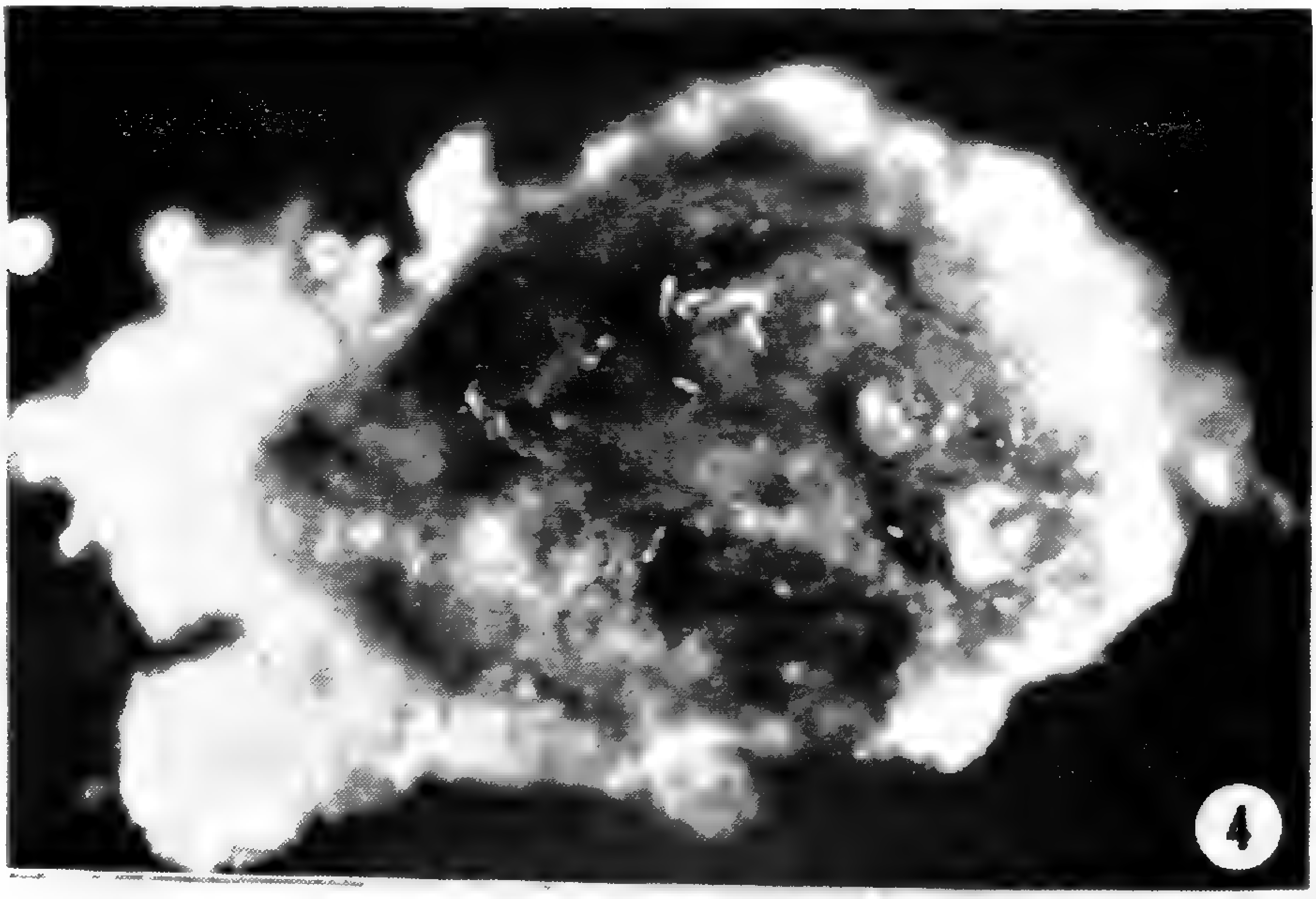
Massulae with long, slender, hairlike or filamentous, nonseptate glochidia. Glochidia tips equal in diameter to the distal portions of the glochidia and lacking terminal structural differentiation, slightly enlarged or inflated, or coiled. Megaspores and vegetative remains unknown.

TYPE: *Azolla circinata* Oltz & Hall.

Section *Filifera* includes massulae with glochidia which tend to resemble the perisporal hairs on the body of many *Azolla* megaspores, both living and fossil. Although megaspores with coiled perisporal hairs or with hairs having enlarged tips have not been reported, they do occur in some of the Cretaceous deposits which I have examined; furthermore, there are massulae with straight, unbranched glochidia in some of these deposits. All of these await further, detailed study before their relationships and taxonomy can be clarified. My present opinion is that this section is primitive in *Azolla* because glochidia and megaspore ornamentation are only slightly, if at all, different.

AZOLLA **circinata** Oltz & Hall, sp. nov.

Massulae nearly circular to oval in outline, ca. 100–175 μ in longest dimension, 75–150 μ in shortest dimension, the surface often marked with wide, rugulo-reticulate thickenings, these sometimes circular and overlapping, giving the massulae a foamy aspect. Glochidia numerous, 1–2 μ wide, up to ca. 15 μ long, usually not extended greatly beyond the margin of the massula proper, variously coiled at the apex, some appearing merely inflated at the tip, usually with 1 gyre, or sometimes with only a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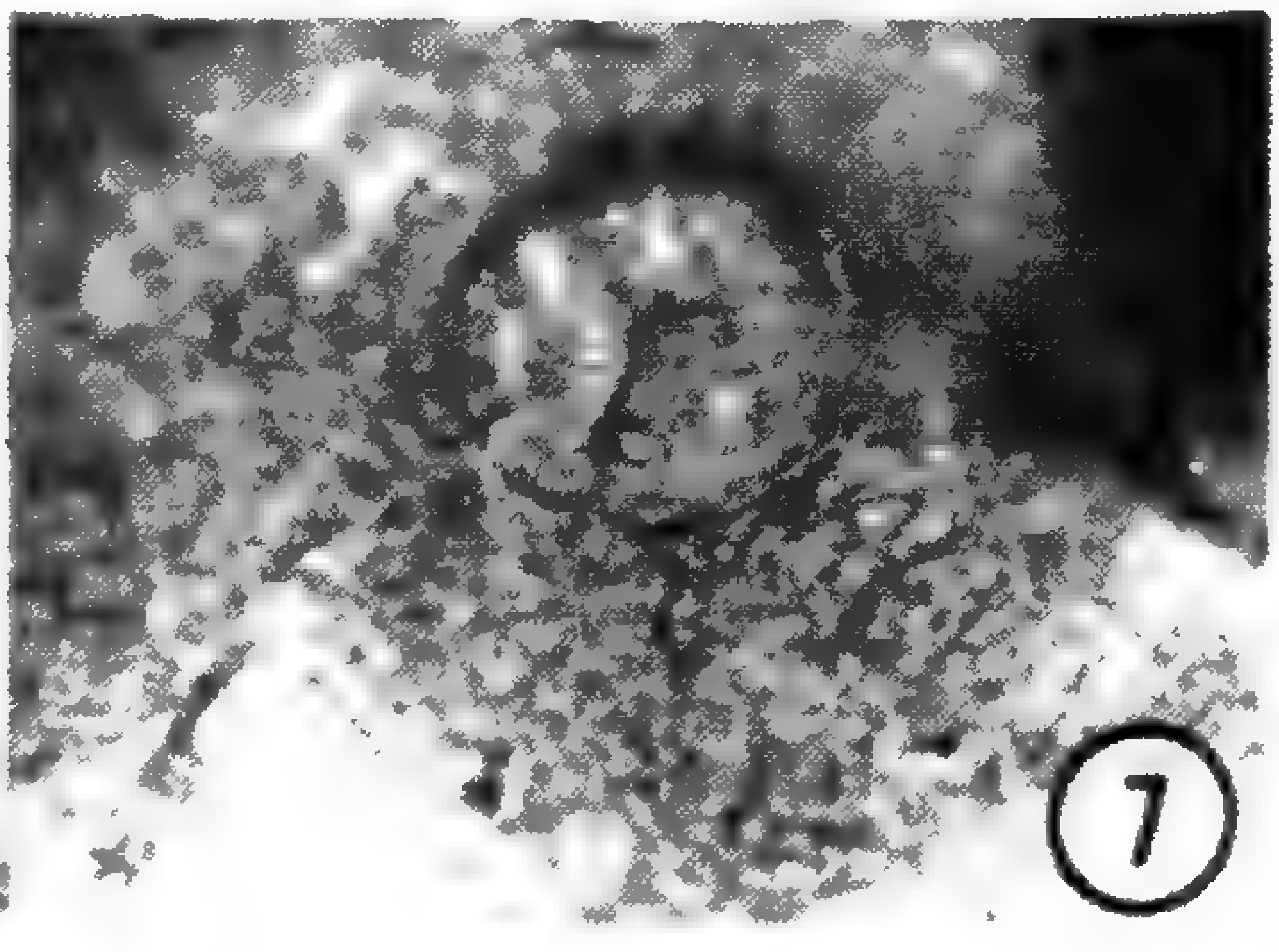
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AZOLLOPSIS COCCOIDES

partial gyre. Microspores small, often completely obscured by the plasmodium of the massula, 20–24 μ in diam., probably psilate and thin-walled. Megaspores and vegetative remains unknown.

TYPE: Slide HH 16, coordinates 38.6 × 105.2, reference 48.0 × 122.1 (paleobotanical collections, MIN), from the Hell Creek Formation (Maestrichtian) near the center of S16, T25N, R43E, McCone Country, Montana. *Fig. 1.*

Azollopsis J. W. Hall, gen. nov.

Megaspore apparatus with a conspicuous, tomentose perispore and a spherical, trilete endospore. Numerous float-like structures imbedded in or attached to the hairs of the perispore. Massulae with few microspores and conspicuous multi-hooked or barbed glochidia. Vegetative remains unknown.

TYPE: *Azollopsis coccoides* J. W. Hall.

The long, tortuous but otherwise unstructured hairs of the perispore are like those on the megaspores of species of *Azolla*, but the mass of them is greater than in that genus. The floats are relatively small, very numerous, and scattered throughout the hairs of the perispore or attached to them at the surface of the spore. The number, size, and position of the floats serves to distinguish *Azollopsis* from *Azolla*, as do the barbed glochidia of the massulae.

AZOLLOPSIS **coccoides** J. W. Hall, sp. nov.

Megaspore apparatus spherical to oval, as in the genus, 560–990 μ (aver. 706 μ) overall[2]; megaspore walls finely foveolate, 6–9 μ thick. Floats very numerous, 40–90 μ (aver. 72 μ) in diam., circular in outline, disk-shaped, sculptured as in *A. tomentosa.*

Massulae attached to the megaspore, ca. 120 μ in diam.,[3] with only 2 or 3 spores each, these circular, 44–50 μ (aver. 47 μ) in diam., with laesurae extending to the equator, the surface

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[2] Intact endospores could not be measured because all are obscured by the tomentose perispore.

[3] The exact limits were mostly obscured because the massulae were deeply imbedded in perisporal hairs and merged with the floats.

FIG. 4. HOLOTYPE IN REFLECTED LIGHT, × 90. FIG. 5. SAME, IN TRANSMITTED LIGHT, × 90. FIG. 6. GLOCHIDIA FROM A MASSULA OF THE PARATYPE, × 400. FIG. 7. MICROSPORE IN MASSULA FROM THE PARATYPE, × 400.

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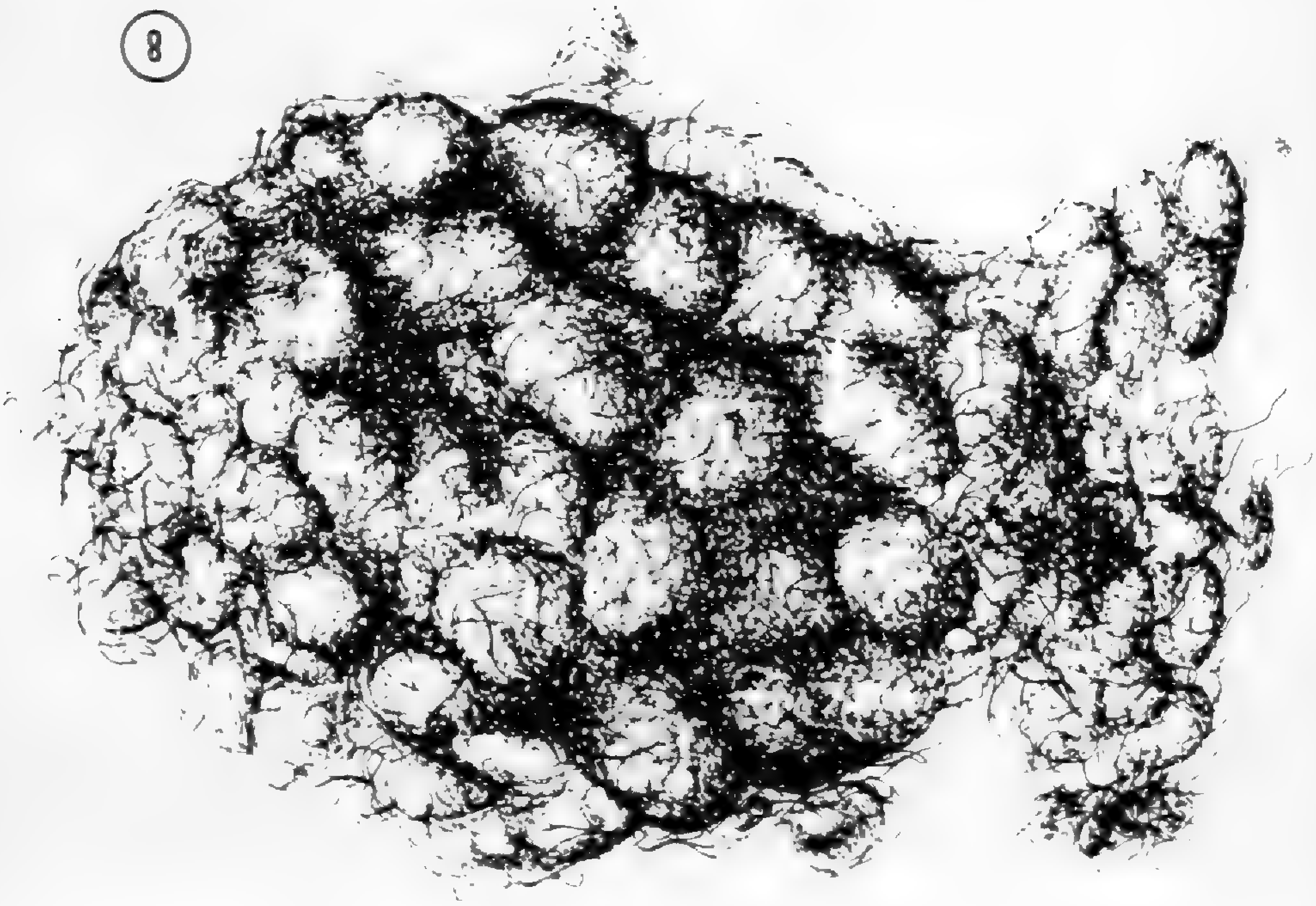

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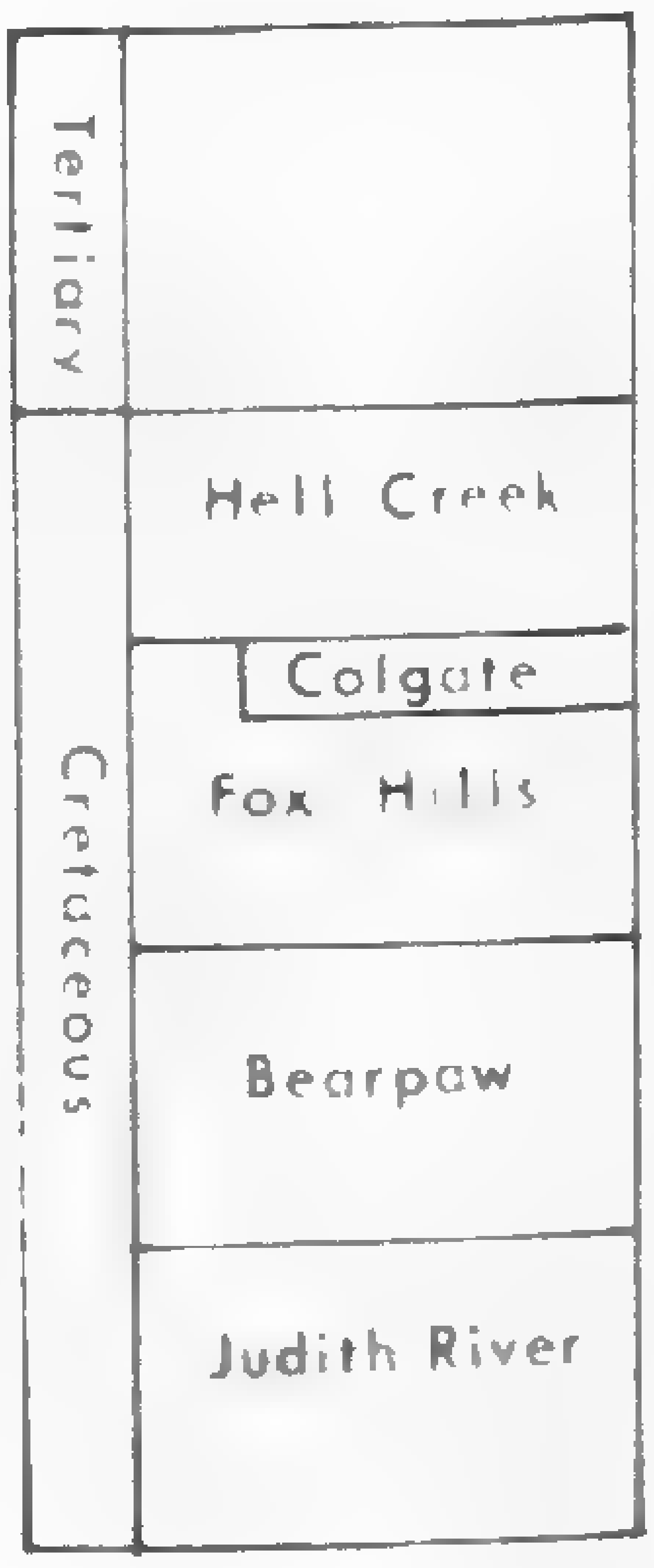

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FIG. 8. DRAWING OF THE HOLOTYPE OF AZOLLOPSIS COCCOIDES (CF. FIGS. 4 AND 5), × 90. FIG. 9. GLOCHIDIA OF AZOLLOPSIS TOMENTOSA (CF. FIG. 12), × 450. FIG. 10. GLOCHIDIA OF A. COCCOIDES (CF. FIG. 6), ×900. FIG. 11. DIAGRAM OF STRATIGRAPHIC COLUMN IN EASTERN MONTANA SHOWING RELATIVE POSITION OF FORMATIONS IN WHICH AZOLLA CIRCINATA AND AZOLLOPSIS SPP. OCCUR.

probably psilate and the wall 1–2 μ thick. Glochidia numerous, barbed, distinctly septate, 2–5 μ wide, with 6–15 barbs arranged in 2 rows, each glochidial "cell" with 2 opposite barbs.

TYPE: Slide 223–3 (paleobotanical collections, MIN), from the Judith River Formation, Upper Cretaceous (Campanian), at the west end of the Fort Peck Reservoir at the "Robinson Bridge," Philips County, Montana. *Figs. 4, 5, 8,* and *10.*

PARATYPE: Slide 223–1, coordinates 134.8 × 51, reference 131.8 × 72.3 (paleobotanical collections, MIN). Locality as for the holotype. *Figs. 6, 7,* and *10.*

The holotype possesses both megaspores and massulae, but the glochidia of the latter are seen to better advantage in the paratype. Except for the slightly larger dimensions, which may not be significant because of the smaller number of specimens seen, the megaspores of this species are virtually identical to those of *Azollopsis tomentosa*; the differences between the two species are in the massulae. The only massulae seen were those attached to the megaspores, and every megaspore had several massulae attached. The apparent effectiveness of their attachment, to the extent that they are surrounded by floats and perisporal hairs, contrasts sharply with their lack of attachment in *A. tomentosa*. Compared with that species, *A. coccoides* has fewer spores per massula, laesurae extending to the spore equator, narrower, distinctly septate glochidia with numerous barbs, and smaller massulae.

AZOLLOPSIS **tomentosa** J. W. Hall, sp. nov.

Megaspore apparatus spherical to oval,[4] as in the genus, 462–924 μ (aver. 680 μ) overall; endospores 400–480 μ (aver. 430 μ) in diam. Megaspore surface foveolate, sometimes slightly scabrate to psilate, the wall 6–8 μ thick. Floats numerous, ca. 60 μ in diam., circular in outline, but sometimes oblate in side view and disk-shaped rather than spherical, the surface composed of irregularly arranged granules and rods, sometimes vaguely reticulate and with the vacuolate aspect found in the floats of species of *Azolla*. Floats occurring only at the periphery of the perispore and extending

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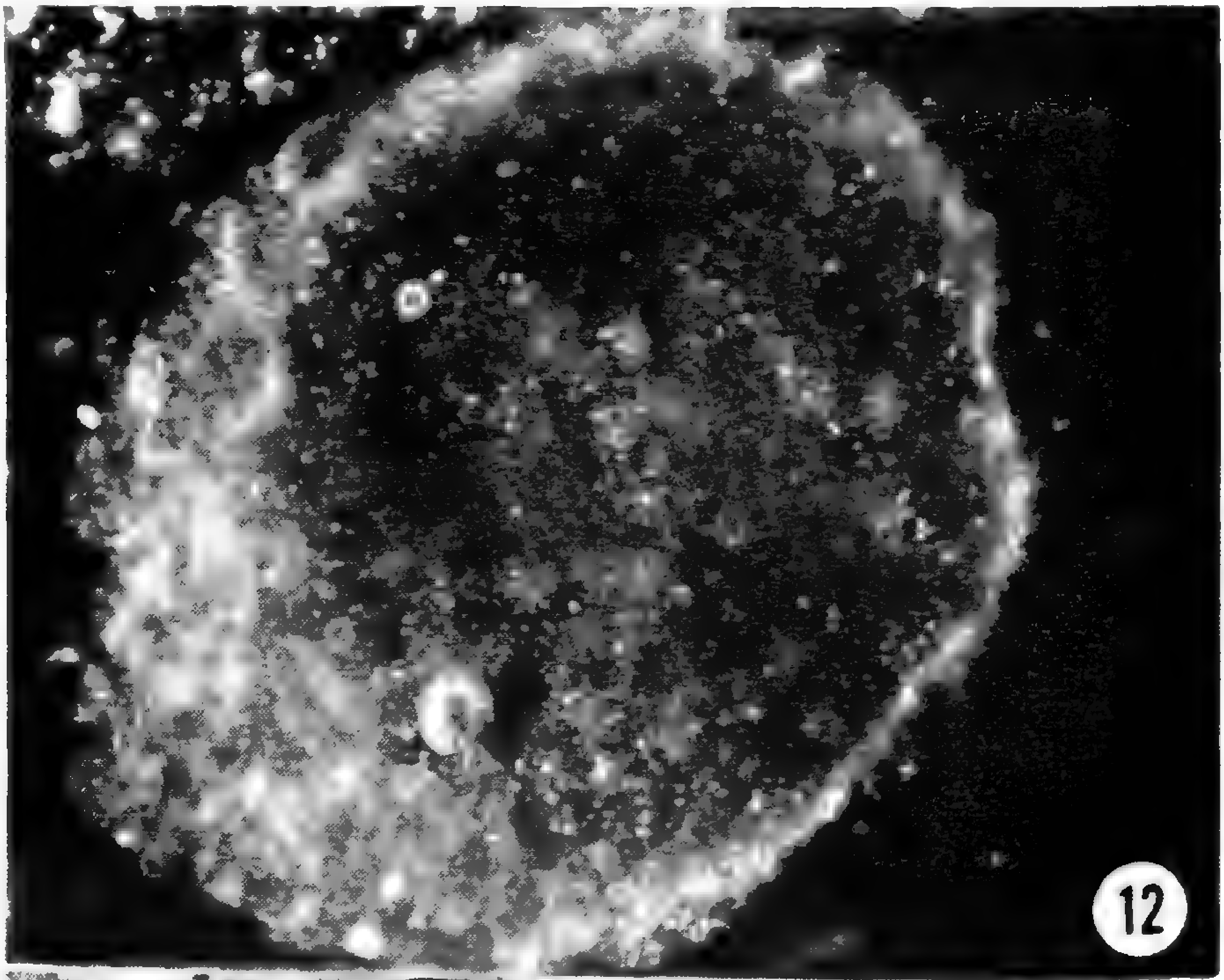
[4] The latter shape is due to the greater mass of floats and perisporal hairs at one end of the spore; it cannot be determined whether this is the distal or proximal end because laesurae are not often seen.



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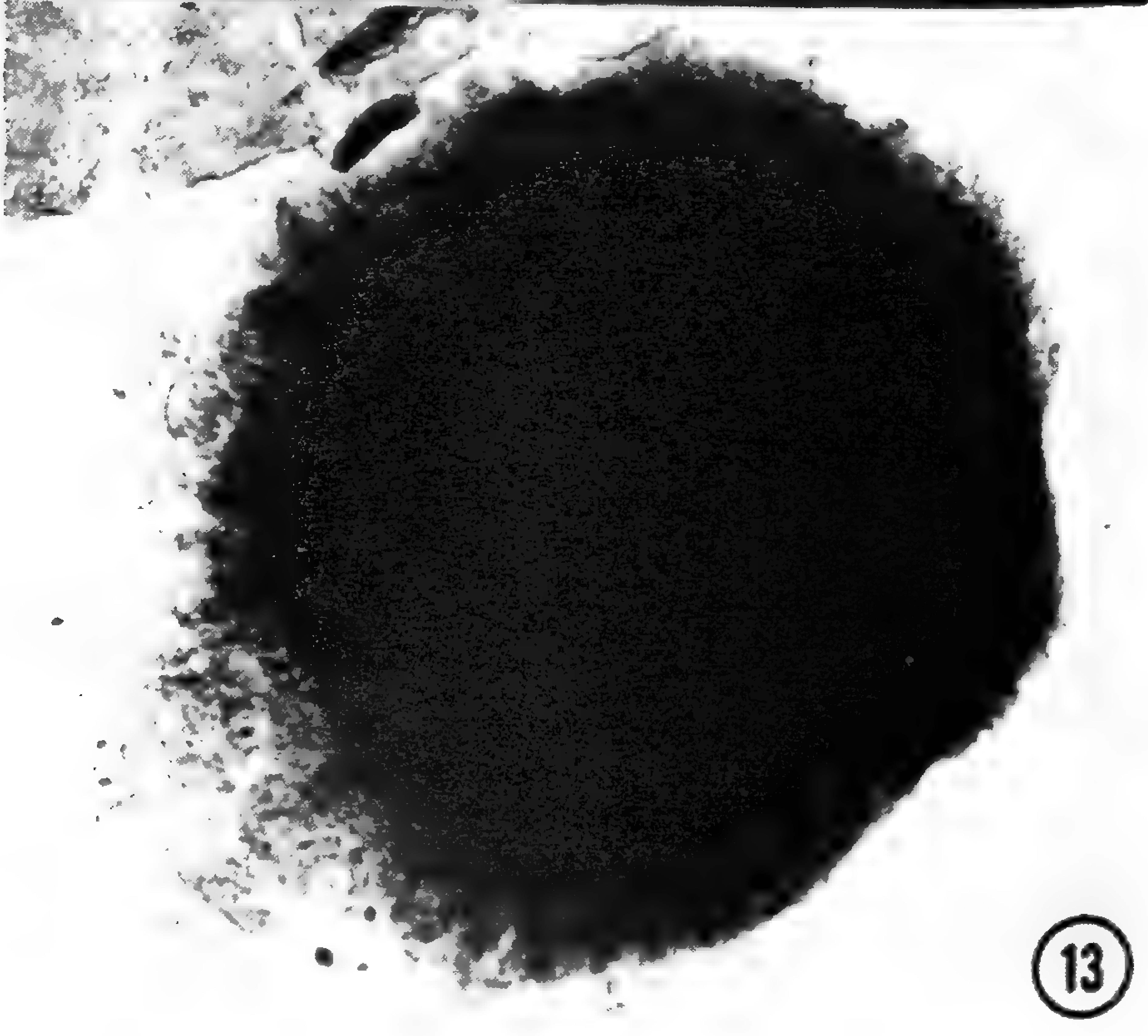

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HOLOTYPE OF AZOLLOPSIS TOMENTOSA

beyond its margin or completely surrounded by the tomentose hairs.

Massulae variable in size and shape, mostly oval to subcircular, occasionally elliptical or reniform, 146 × 215 μ to 245 × 630 μ, mostly between 200 × 250 μ and 200 × 300 μ. Surface of the massulae with numerous, septate or non-septate glochidia ca. 60–90 μ long, 6–10 μ wide, each with 4–6 retrorse barbs, one of these terminal. Microspores usually 4–8 (sometimes 12) per massula, 25–50 μ in diam., probably psilate, with short laesurae.

TYPE: Slide 208–11, coordinates 59.6 × 139.1, reference 67.8 × 132.8 (paleobotanical collections, MIN), from the Colgate member, Fox Hills Sandstone, Upper Cretaceous (Maestrichtian), in S16, T13N, R55E, Dawson County, Montana. *Figs. 12* and *13*.

PARATYPES: Slide 208–1, coordinates 38.0 × 124.5, reference 12.1 × 119.5 (*Fig. 2*) and coordinates 35.8 × 125.4, reference 12.1 × 119.5 (*Fig. 3*) (both paleobotanical collections, MIN). Locality as for the holotype.

The massulae of this species are extremely large; some of them approach the size of megaspores. None has been found attached to the megaspores, but this may be due to their being dislodged during preparation. The glochidia are stouter in this species than in *A. coccoides*, are less conspicuously septate, and have fewer barbs.

DISCUSSION

The term "float" is applied to the spherical objects in the perispore of the megaspore apparatus of *Azollopsis* in deference to its use in *Azolla*, although in that genus, as has been pointed out by many authors, the term is a misnomer, for the megaspores sink shortly after being shed. Whether this was also the case in *Azollopsis* will never be known, but, at least superficially, the so-called floats seem to increase the surface area. They are not hollow, and any supportive function would have come from their numerous vacuolar cavities. Those floats that cling to the periphery of the megaspore resemble small, glochidia-less massulae, and it was my first impression that this was actually what they

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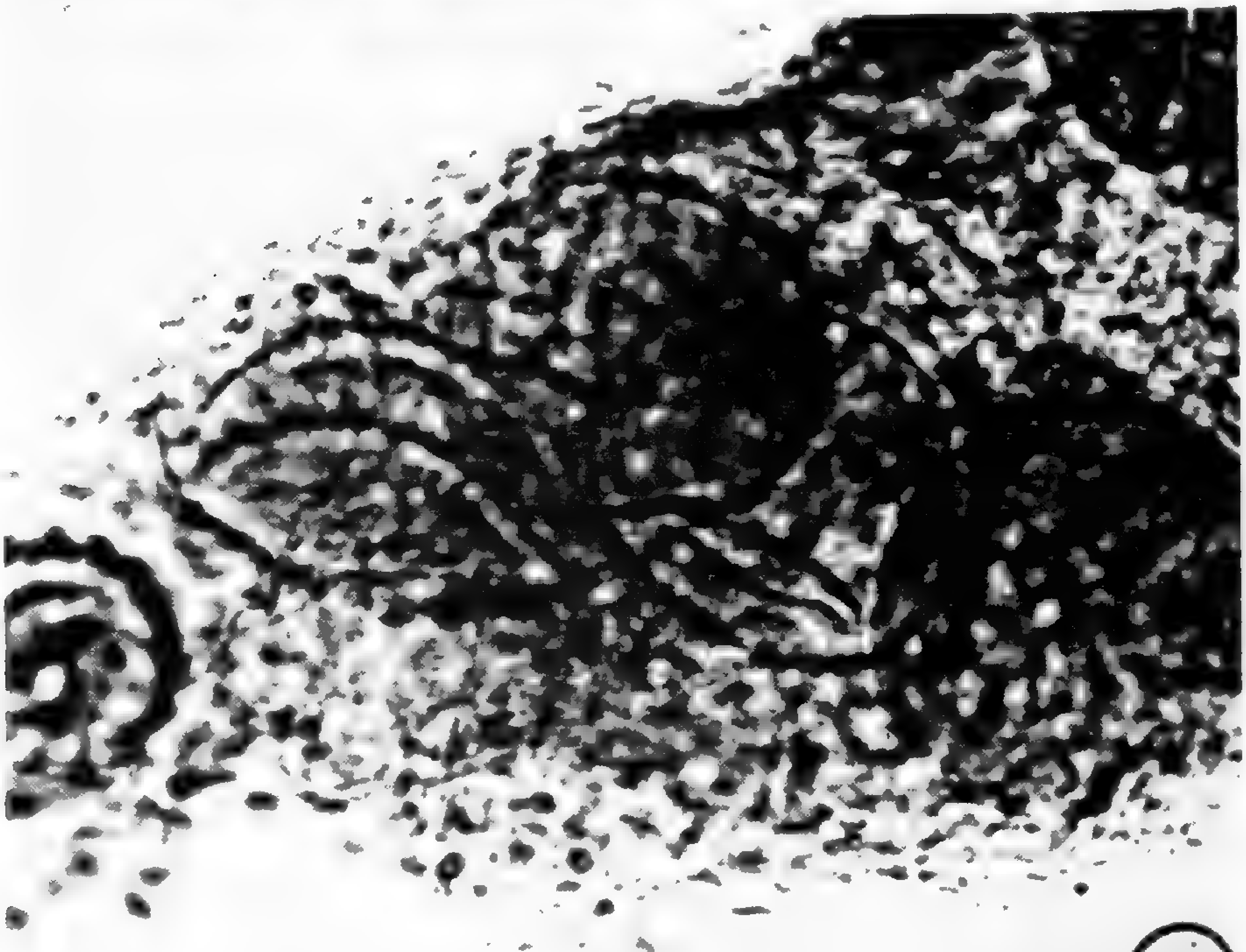
FIG. 12. MEGASPORE IN REFLECTED LIGHT, × 100. FIG. 13. SAME, IN TRANSMITTED LIGHT, × 100.



AZOLLOPSIS TOMENTOSA

were. However, there are several reasons why they cannot be massulae, the most important being the lack of microspores; another is their presence deep among the perisporal hairs, where it is unlikely that a massula would be able to penetrate; and a third, of course, is the occurrence of massulae with barbed glochidia actually attached to the megaspore in *A. coccoides.* If one can attribute to *Azollopsis* the kind of ontogenetic development of the megaspore and its swimming apparatus of *Azolla,* then the position of the floats, their large number, and their structure may be explained readily.

In the development of the megasporangium of *Azolla* there are 32 spores, separated by a periplasmodium derived from the tapetum of the sporangium, and all but one spore aborts (Eames, 1936, p. 250). The periplasmodium and abortive spores fill the upper part of the sporangium, above the developing megaspore; three vacuoles appear in the plasmodial mass, the degenerating nuclei are distributed into each vacuolar region, and a float develops from each. The developing megaspore also lies in a vacuole filled with a cytoplasmic fluid that becomes granulate. This cytoplasm develops into a foamy meshwork, and a perispore is formed, having a structure similar to that of the floats. Perisporal hairs then develop over the surface of the perispore; these seem homologous with glochidia. A float is the homologue of a massula.

Only a slight departure from this pattern would produce the numerous floats of *Azollopsis.* If, instead of aggregating apically, the aborting spores remained scattered around the developing megaspore, and if each aborting spore developed in association with a small periplasmodial mass, the situation in *Azollopsis* would arise. Furthermore, if the development of floats occurred just prior to the formation of perisporal hairs (as in *Azolla*), many of the floats would then be surrounded by hairs. This presumed developmental pattern is somewhat like that for the development of the massulae, with microspores, in *Azolla.* Since massulae and floats are homologous in that genus, they probably are in *Azollopsis*

FIG. 14. SEPTATE AND NON-SEPTATE GLOCHIDIA (CF. FIGS. 1 AND 2), × 1045.
FIG. 15. MICROSPORES IN MASSULA, × 1045.

as well; the resemblance of floats to glochidia-less massulae is not difficult to imagine.

The Judith River Formation, in Montana, is stratigraphically below any horizon from which remains of the Salviniaceae have been recovered until now. It lies in the Campanian stage of the European sequence; the Colgate Member, Fox Hills Sandstone is younger, and is in the Maestrichtian stage. *Fig. 11* shows the stratigraphic relationships of the formations involved. The fluvial Judith River sediments were covered by a transgressing Bearpaw sea; when this regressed, the Fox Hills Sandstone was deposited; the Colgate Member is its uppermost, most shoreward phase. The Hell Creek Formation is again fluvial. *Azollopsis* must have occupied a non-marine refugium during Bearpaw and Fox Hills times, and then moved eastward, as the evolved species *A. tomentosa*, by Colgate times. The record of other pollen and spore types is not yet well enough known to substantiate this suggestion, but the small mammals apparently do. There are generic, but not specific, similarities in small mammals in the Judith River and Hell Creek formations (A. Sahni and R. E. Sloan, pers. comm.). Additional examples demonstrating species evolution in the floras of these two formations can thus be expected.

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DEPARTMENT OF BOTANY, UNIVERSITY OF MINNESOTA, MINNEAPOLIS, MINN. 55455.

Shorter Notes

NOTES ON WOODWARDIA AREOLATA AND OTHER RARE ILLINOIS FERNS.—On January 7, 1967 I discovered *Woodwardia areolata* (L.) Moore in a marshy seep spring nine miles northeast of Paducah, Kentucky, in southern Pope County (*Schwegman 1089*). Since this collection was of dead material, I returned to collect some live specimens on June 17, 1967 (*Schwegman 1250*). Both specimens are in the herbarium of Southern Illinois University (SIU). This station is about 40 miles north of stations for the Net-veined Chain Fern in Calloway County, Kentucky, and about 80 miles northeast of the stations in southeastern Missouri. The seep spring in which the specimens were found is a common habitat in the area of sandy, Cretaceous hills in southern Illinois. I have visited about 40 springs, but have found no other stands of *Woodwardia*. The *Woodwardia* dominates about a third of the spring, which measures about 40 feet long and 25 feet wide. The spring is in a dry oak-hickory woods, but *Acer rubrum* grows at its edge. *Boehmeria cylindrica* dominates another part of the spring, and *Impatiens biflora, Polygonum punctatum, Carex incomperta, C. crinita, C. laevivaginata*, and *C. lurida* are also present. The only other fern at this spring is *Athyrium filix-femina*. Ferns typical of adjacent springs include *Athyrium filix-femina, Onoclea sensibilis, Osmunda regalis, O. cinnamomea,* and *Thelypteris palustris*. *Ophioglossum vulgatum* was seen at one spring.

Thelypteris noveboracensis (L.) Nieuwl. is rare in Illinois. The only previous specimen from southern Illinois was collected in Jackson County in 1880. I collected the New York Fern in damp, sandy soil of a small seep spring about 2.5 miles northwest of the *Woodwardia* station and 3.5 miles southwest of Bay City, Pope County, on June 27, 1967 (*Schwegman 1268*, SIU). The spring is on a north-facing wooded slope; the habitat is only slightly more moist than average for this hillside. The fern is in a circular stand about six feet in diameter. It is surrounded by *Athyrium filix-femina*, which it superficially resembles.

Dryopteris goldiana (Hook.) Gray is seldom collected in Illinois, and apparently is very rare in the southern half of the state; the only previous collection is from Jackson County. I discovered clumps of this fern growing with *D. marginalis* in rocky woods at the base of a north-facing hill along Lusk Creek, SW¼, S21, T12S, R6E, Pope County, on August 18, 1967 (*Schwegman 1367*, SIU).

I found *Ophioglossum engelmannii* Prantl, a fern of exposed limestone habitats, growing rather abundantly in limestone hill prairie on Millstone Knob, which is near Robbs, Pope County, on June 4, 1966 (*Schwegman 454*, SIU).

I want to thank Professor Robert H. Mohlenbrock of Southern Illinois University, whose encouragement and interest in my collecting helped make this paper possible. JOHN SCHWEGMAN, *Mermet Wildlife Refuge, Belknap, Ill. 62908.*

A SPINY DENNSTAEDTIA FROM CENTRAL AMERICA.—During a course in tropical pteridophytes for the Organization for Tropical Studies last summer in Costa Rica, I found a new species of *Dennstaedtia* which is remarkable in having spiny stipes, rachises, and pinna axes, a condition found in no other New World species of the genus.

DENNSTAEDTIA **spinosa** Mickel, sp. nov.

Frondes fere 2 m longae, axibus spinulosis, spinulis usque ad 3 mm longis rectis vel paullo antrorsis; laminae quadripinnatipinnatifidae; pinnae alternae, supra nitentes et fere glabrae, subtus hirsutae, pilis rectis hyalinis; venae apice tenues; indusia humilia lata plus minusve bivalvata, integra vel irregulariter dentata; sporae triletae, rugosae, rugis brevibus latis irregulariter coalescentibus.

Rhizomes creeping, clothed with black hairs; fronds nearly 2 m long; axes orange, spiny, the spines up to 3 mm long, straight or slightly antrorse; stipes ca. 1 m long, 1 cm thick; blades approx. 1 m long, 1 m broad, deltoid, quadripinnate-pinnatifid, lacy; pinnae alternate, short-petiolulate (to 12 mm); basal pinnules opposite, not or only slightly reduced, the larger 10–13 cm long, 2.5–3 cm broad; laminae hirsute beneath with straight, hyaline hairs, shiny above and essentially glabrous; vein endings slender; sori small, ca. 0.6 mm broad; indusia entire to irregularly dentate, low, broader than high, more or less bivalvate; spores trilete, with short, broad, irregularly coalescing ridges, 27.0–32.5 μ in diameter.

TYPE: Costa Rica, Province of Puntarenas, Osa Peninsula, southwest of Rincón de Osa, in rain forest behind Tropical Science Center field station, ca. 50 m alt., *Mickel 2730* (US; isotypes ISC, LP, USJ).

PARATYPE: Honduras, in forest on ridge above Lancetilla, *Yuncker 4592* (US).

This new species closely resembles *D. cicutaria sensu lato* but can be distinguished readily by the spiny axes and finer dissection. *Dennstaedtia spinosa* has distinctive internal anatomy and spore morphology as well. The petiole trace of *D. cicutaria* is extremely corrugated on the abaxial arc and has much higher lateral bulges. The stipe bundles of *D. spinosa,* on the other hand, are smooth and uncorrugated on the abaxial side, and the lateral bulges are lower. The lateral grooves are so deep as to touch one another in the center of the stipe. In their rhizomes both species have dicyclic solenosteles, but those of *D. cicutaria* are dorsiventral with the ventral side slightly corrugated and those of *D. spinosa* are terete and uncorrugated. The spores also differ; those of *D. cicutaria* are verrucate, whereas those of *D. spinosa* have low, irregularly anastomosing ridges. Furthermore, the indusia of the new species are more regularly dentate than are those of *D. cicutaria.*

Although *D. cicutaria* occasionally has a few prickles on its axes and a few specimens, described as *D. decomposita,* are as dissected as *D. spinosa,* none has the regular and consistent spininess nor the anatomical and spore characteristics of *D. spinosa.* I have seen no Old World specimens of *Dennstaedtia* that closely approach the new species, and it seems clear that it belongs to the *D. cicutaria* complex.

JOHN T. MICKEL, *Department of Botany and Plant Pathology, Iowa State University, Ames, Iowa 50010.*

POLYSTICHUM MUNITUM IN SOUTH DAKOTA.—While collecting for the University of Kansas I discovered a small patch of *Polystichum munitum* (Kaulf.) Presl on a moist, grassy, shaded stream bank in the Black Hills of South Dakota three miles southwest of Rochford in Pennington County. This is the first record of the fern in South Dakota and extends the present range some 550 miles to the east from near Missoula, Montana. Elsewhere in North America it is known from Alaska to Montana and southward to California and Idaho. The numerous teeth of the long, narrow, sword-shaped pinnae are bristle tipped. This and the linear-lanceolate leaf distinguish the fern from other western species. The identification of the specimen, *Ralph Brooks 427* (KANU), was verified by Dr. Ronald L. McGregor.—RALPH BROOKS, *5611 Maple St., Mission, Kansas 66202.*

TRICHOMANES PETERSII REVISITED AT SARATOGA, MISSISSIPPI.—During the summer of 1965, while teaching at the University of Southern Mississippi, I learned from Mr. R. N. Dean of the existence of a colony of the rare *Trichomanes petersii* Gray at Saratoga, Simpson County, Mississippi, between Jackson and Hattiesburg. At that time Mr. Dean was a student at Valdosta State College. He, in turn, had been told about the colony by a local high school teacher. In September 1965 I used Mr. Dean's map to locate the colony of a few plants growing on a very damp outcrop of ferruginous sandstone. I collected a very small specimen which is deposited in the University of Mississippi Herbarium. Recently, I found that E. T. Wherry[1] had visited the site in 1936. Almost 30 years later I could still follow Wherry's description of the area in order to locate the colony. The site, however, had been timbered and burned, apparently reducing the size of the colony from what it was in 1936.—SAMUEL B. JONES, JR., *University of Georgia, Athens, Ga. 30601.*

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[1] Wherry, E. T. 1936. Trichomanes petersii at Saratoga, Mississippi. Amer. Fern J. **26:** 141–142.

LYGODIUM MICROPHYLLUM, ANOTHER FERN ESCAPED IN FLORIDA.—Two species of climbing ferns (*Lygodium*) have been reported from Florida. *Lygodium palmatum* (Bernh.) Swartz is a native of the eastern United States that has been recorded from Florida by several authors, including Chapman,[1] Small,[2] Correll,[3] and Spurr.[4] For each report, however, some doubt has arisen, and its status in our flora has remained unsatisfactory.

The other species, *Lygodium japonicum* (Thunb.) Swartz, is all too evident in many areas. It is an introduction from eastern Asia that has spread aggressively into moist woods and fields in most parts of Florida and adjacent states. It is largely lacking in southern Florida however. The University of Florida Herbarium has a March, 1932, collection from Dade County by the late Mary Diddell, "escaped on vacant lots, Miami," but it has not persisted on any scale, if at all, in that area. More recent collections and field observations show the southern limits to be near Tampa Bay and in Highlands County.

The above range data take on a special interest since the University of Florida Herbarium has recently acquired several collections of an escaped *Lygodium* from Martin County, in southeastern Florida: "On mainland opposite Jupiter Island" and "Cabbage Palm Hammock on mainland, opposite Jupiter Island." (both *L. D. Ober*, 15 June 1965) and "Jonathan Dickinson State Park. No fruiting plants." (*Carl W. Campbell*, 12 Nov. 1966). These represent an apparent recent introduction that is established and spreading in the area, *Lygodium microphyllum* (Cav.) R. Brown. This species is found throughout the Old World tropics from Africa to Australia, Asia, and Melanesia. It has long passed under the name *Lygodium scandens* (L.) Swartz, but Holttum[5]

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[1] Chapman, A. W. 1897. Flora of the Southern United States, p. 635.

[2] Small, J. K. Flora of the Southeastern United States, 2nd Ed., p. 5. 1913.; Ferns of Florida, pp. 47–48. 1931; Ferns of the Southeastern States, pp. 336, 337, 339. 1938.

[3] Correll, D. S. 1938. A County Check-List of Florida Ferns and Fern Allies. Amer. Fern J. **28**: 46–48.

[4] Spurr, S. H. 1941. Notes on the Distribution and Habits of the Ferns of Northern Peninsular Florida. Proc. Fla. Acad. Sci. **5**: 64.

[5] Holttum, R. E. 1959. Flora Malesiana, Series II, Vol. 1, part 1, pp. 44–51, fig. 5–8.

has recently rejected this name. It is worth noting that Holttum refers to this plant as "sometimes a weed," and indicates various disturbed habitats for it.

A clue to the origin of these escaped plants is given by a collection "in nursery, Delray Beach, Palm Beach Co." (*R. A. Long*, 11 Feb. 1958). This is immediately south of the Martin County area. No doubt, Palm Beach County would yield colonies of the species if carefully searched.

Since Holttum gives detailed descriptions and illustrations of *Lygodium japonicum* and *L. microphyllum*, there is little need to discuss their differences at length here. *Lygodium japonicum* has palmate to pinnately deeply lobed sterile leaflets which are not articulate at the bases. *Lygodium microphyllum* has articulate sterile leaflets that are unlobed or but infrequently lobed. The leaflets bear a superficial resemblance to those of *Nephrolepis cordifolia*.

It will be very interesting to watch the future spread and behavior of *Lygodium microphyllum* in Florida. It has presumably undergone several colder than average winters, so it should be able to maintain itself in this climate. Assuming it spreads out to overlap the range of *L. japonicum* to the northwest, we will be able to witness an experiment in competition between two closely allied and ecologically similar species.—JOHN BECKNER, *Department of Botany, University of Florida, Gainesville, Florida 32601.*

Notes and News

FERN FORAY RESERVATIONS for September 1 and 2 should be made through Dr. Clara Frederick, Urbana College, Urbana, Ohio 43078. You may also write directly to the Holiday Inn Motel, Chillicothe, Ohio 45601. In either case, please write to Dr. Frederick, stating what reservations you have made or wish to make and whether you need transportation or can provide it for other participants. Rates at the motel are $9.00 for single rooms, $11.00 for double-bed rooms, and $14.00 for twin-bed rooms.

SOCIETY LUNCHEON RESERVATIONS should be made with Dr.

Jane Decker, Department of Botany, Ohio State University, Columbus, Ohio 43210. The luncheon will be at noon on Tuesday, September 3.

FERN WALK IN WASHINGTON, D. C. Dr. James Johnston will lead a walk in Rock Creek Park at 2:00 PM on Sunday, July 14, 1968, starting at the foot trail at 16th Street N.W. opposite Whittier Street (*not* Whittier Place), which is two blocks south of Aspen Street, the southern boundary of Walter Reed Hospital. The walk is one of a series of guided nature walks on various topics held under the auspices of the National Park Service. A ranger naturalist from the Rock Creek Park Nature Center will also accompany the group. Details of seasonal growth and development of certain fern species will be featured.—D. B. L.

POLYPODIUM DECUMANUM NEEDED.—I wish to obtain living material, either rhizomes or spores, of the large epiphytic fern of the Caribbean region *Polypodium decumanum*, sometimes known incorrectly as *Polypodium leucatomos*. Does any member know where it can be obtained?—EDGAR T. WHERRY, *Leidy Laboratory, University of Pennsylvania, Philadelphia, Pa.* 19104.

FERNS AVAILABLE.—I have a number of live ferns for exchange or as a gift. If the latter, please send postage. A list of species is available.—DR. I. KNOBLOCH, *Department of Botany and Plant Pathology, Michigan State University, East Lansing, Mich. 48823.*

Recent Fern Literature

AN ANNOTATED BIBLIOGRAPHY OF MEXICAN FERNS, by George Neville Jones. xxxiii + 297 pp. Univ. of Illinois Press, Urbana, 1966. $5.00. In this useful volume Professor Jones has amply fulfilled his aim of providing "a useful bibliography of the principal literature pertaining to Mexican ferns." The extensive cross indices (about 3,000 entries) lead to more than 1,200 annotated references arranged by author. Bibliographic citations run only through 1962, which is understandable considering the lengthy and diverse cross indices, which must have taken years to prepare. A few examples among the cross reference categories are general indices to annotated catalogues, bibliography, ecology, ethnology, exploration and collection, floras and revisions, herbaria, horticulture, and nomenclature. There are also special biographic, geographic, and taxonomic indices. The title of the book is exceedingly modest, for the range of material far surpasses the boundaries of Mexican ferns. The book will therefore be useful to all pteridologists, even those whose interest in Mexican ferns is slight.—D. B. L.

TWO CHINESE FERN BOOKS.—Two books by Shu-hsia Fu have recently come to my attention. One is called (transliterated) "Chung-kuo chüeh lei chih wu chih shu," which may be translated "Genera of Chinese Ferns and Fern-allies." It is in the Oriental Section of the Library of Congress, no. QK 529 F8 1954. It contains descriptions and keys to the genera, but unfortunately these are not usable, being wholly in Chinese, and also many line drawings. A number of combinations, mostly or all attributed to Ching, are indicated as new, but these are not validly published, since the place of publication and dates are not cited, as required by the Code for works published since January 1, 1953. The second book, "Chung-kuo chu yao chih wu t'u shuo," i.e., "Illustrations of Important Chinese Plants: Pteridophyta" (no. QK 529 F78 1957), is similar except that the illustrations are larger and better. Again the book is wholly in Chinese. A validly published new combination is *Gymnopteris vestita* var. *auriculata* (Franch.) Ching (p. 85), which is cited as based on *Gymnogramme vestita* var. *auriculata* Franch. Nouv. Arch. Mus. Paris **10:** 123. 1887. *Gymnocarpium continentale* (p. 129) also meets the requirements for valid publication, but the combination is superfluous, having been made by Pojarkova in 1950. The combination *Dryoathyrium viridifrons* var. *okuboanum* (Makino) Ching (p. 125) is not validly published because the basionym cited, *Aspidium okuboanum* Bot. Mag. Tokyo **6:** 47. 1892, is a nomen nudum at the place cited. These two publications indicate that some good work in botany is being done in China, but that it is unusable to western botanists, both because the books are so rare in western institutions and because they are written wholly in Chinese, which most botanists are unable to read.—C. V. M.

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American Fern Journal

A QUARTERLY DEVOTED TO FERNS

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American Fern Journal

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American Fern Journal

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A Culture Chamber for Tropical Rain Forest Plants

DONALD R. FARRAR[1]

A typical greenhouse, although it may function as a tropical house or humid house, usually fails to meet the requirements for growing certain types of tropical plants, notably such rain forest epiphytes as filmy ferns, grammitid ferns, and lycopods. Humidity appears to be the most critical factor for these plants. Temperature and light must also be correct, but they are easier to control. The great success of workers at Kew Gardens and elsewhere in Great Britain in growing these difficult plants has been attributed largely to a climate which enhances efforts to maintain conditions of high humidity, moderate temperature, and indirect light.

My research at the University of Michigan involves the study of fern gametophytes which propagate themselves vegetatively by means of gemmae. Self-propagating gametophytes are found in three primarily tropical fern families: Hymenophyllaceae, Vittariaceae, and Grammitidaceae (Farrar, 1967). The culture of these gametophytes apart from their sporophytes has not been difficult. Most of the variety of techniques commonly used for gametophyte culture are suitable (cf. Stokey, 1930; Steeves et al., 1955; Kleinschmidt, 1957; Miller and Miller, 1961), provided that spores or clean, healthy gametophytes are available as innoculating material. For my own work I prefer the method described by Basile (1964) for the culture of bryophytes. A problem arises, however, when

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[1] I wish to acknowledge the help of Forrest Cochran, W. F. Kleinschmidt, M. F. Tessene, and W. H. Wagner, Jr. in designing and constructing this chamber.

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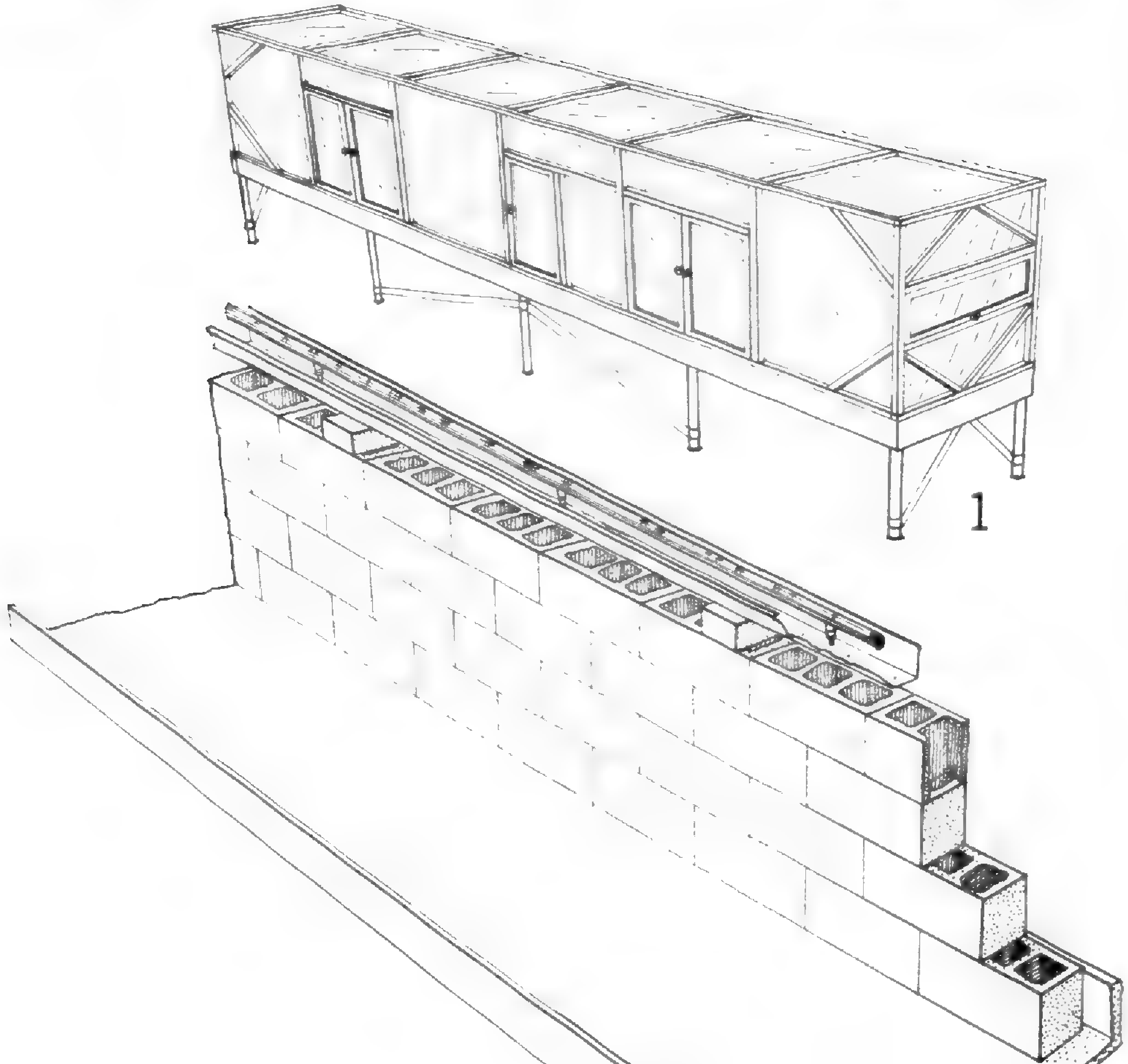

FIG. 1. DIAGRAM OF CHAMBER FRAME. FIG. 2. DIAGRAM OF CONSTRUCTION OF WET WALL.

it becomes desirable to observe in culture the entire life cycle of these ferns, including their sporophytes. Although earlier experience had shown that filmy fern sporophytes could be kept alive in small terraria with a water-saturated atmosphere, the growth rate under these conditions was slow, and the plants could not be examined conveniently. With a knowledge of the British method of growing filmy ferns and with some first-hand knowledge of the natural habitats of these ferns, I constructed in one of the greenhouses at the University of Michigan Botanical Gardens a chamber that would simultaneously maintain conditions of 100% relative humidity, 65°–75°F temperature, and indirect natural light at an intensity not greater than 300 foot candles.

The basic components of the rain forest chamber are (1) an enclosure constructed of redwood and heavy, clear polyethylene plastic film and (2) a wet wall within, all of which is supported by (3) an elevated table that allows for drainage. The chamber frame (*Fig. 1*) is constructed of 2″ × 2″ redwood with doors spaced at convenient intervals, and is covered on the inside and outside by 4 mil (0.004 inch) clear polyethylene film. This produces nearly a two inch wall of insulating air around the chamber and helps to insulate the inside of the chamber from the remainder of the greenhouse. The wet wall (*Fig. 2*) is constructed from 6″ × 8″ × 16″ hollow cinder blocks which are stacked (without mortar) in an interlocking position. The holes run vertically and are filled with sphagnum. The entire wall is kept saturated by water dripping onto the top of the wall from a galvanized trough. The trough has 1/16″ perforations spaced six inches apart and is fed from above by a pipe with mist nozzles spaced three feet apart. Mist nozzles are used because they maintain equal pressure throughout the pipe and thus equalize flow through all the nozzles. This method of maintaining high humidity is favored over direct spraying of the plants because of possible damage from mineral salts in the water. Water flow is controlled either manually, allowing for a slow continuous dripping, or electrically, using a timer which turns the water on periodically to fill the trough. In either case the water drains slowly from the trough into the wall. The latter control method is preferred because of the possibility of a drip flow either stopping or increasing to an undesirable rate due to gradual change in the controlling valves over a period of time. The table supporting the wall is filled with sphagnum to a depth of three inches to increase the evaporating surface and to serve as a large reservoir of moisture in case of failure of the water supply.

A number of problems arose in the development of the chamber. One of these involved the question of how well the chamber would maintain its humidity if the outside water supply were shut off or if the doors were opened repeatedly. When the doors are opened, the humidity immediately drops to near that of the greenhouse. However, the plants have never shown any ill effects from routine use of the doors and, in fact, have shown evidence of drying only when the doors were left open for an hour or more. Humidity rises to nearly 100% within a few minutes after the doors are closed. When the external water supply was shut off, chamber humidity remained near 100% for as long as three days, which was the most extended period tested. However, plants on the wall did begin to dry out in this time. Similarly, plants mounted on fern fiber that was separated from the wet wall by sections of cork oak bark dried out completely within a few weeks, although the relative humidity was maintained near 100%. Considerable water must pass from the wall to the plants via capillarity, which perhaps is similar to "stem flow" in nature, and blockage of this flow causes desiccation.

A second problem was the effect of humidity on metals and wood used in the chamber and in mounting the plants. Redwood was used to make the chamber because of its known decay resistance under humid conditions. The pipe and trough were galvanized steel. The plants were initially potted in six inch plastic pots on a medium of fir bark chips and peat. After becoming established, some were transferred to blocks of fern fiber or sections of tree fern trunk which were fastened against the wet wall. Copper wire was used by mistake in fastening some of the plants to fern fiber sections. Within a month the wire had corroded badly and plants up to one inch from the wire had been killed. The wire was replaced by nylon cord, which has proved to be quite satisfactory.

During the winter months the temperature in the chamber remained near that of the greenhouse (70°-75°F). With increasing solar radiation in the spring it became apparent that the chamber acted as a heat trap; the temperature rose above 90°F on bright, sunny days. After several exposures to temperatures above 80°F some of the plants developed necrotic patches and appeared to have ceased growing. To circumvent this problem a 5000 BTU air conditioner was installed in one end of the chamber. When the air conditioner begins a cooling cycle, relative humidity drops to about 90% because of condensation on the evaporator coils, but rises again to 100% as the air temperature is lowered. Although

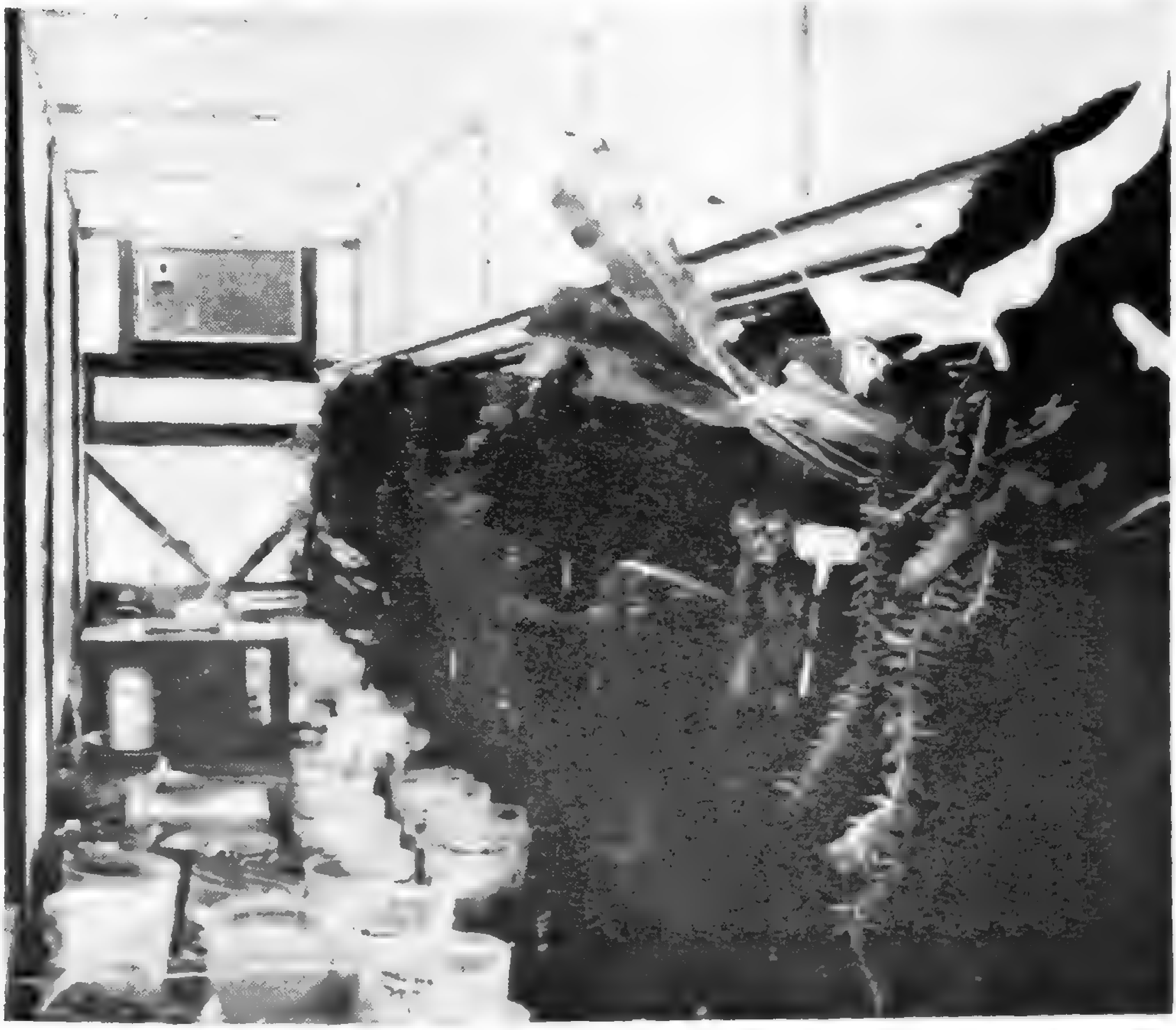

FIG. 3. END VIEW WITHIN CHAMBER SHOWING WET WALL, PLASTIC POTS IN SPHAGNUM, AND AIR CONDITIONER AT FAR END.

an optimum temperature has not yet been established, the plants show excellent growth at 65°–75°F.

Measurements of light intensity that I have made in the field in Costa Rica indicate that rain forest trunk epiphytes (particularly the Hymenophyllaceae and Grammitidaceae) thrive in less than 500 ft-c, and often in less than 100 ft-c. To maintain this low light intensity the greenhouse roof was whitewashed heavily so that no direct sunlight fell upon the chamber. To minimize excess solar light and heat, the chamber should be placed against a north-facing wall.

The chamber is now working well and is highly useful for research with tropical rain forest plants. Such a chamber would also maintain specimens for teaching and display purposes. For the latter purpose a suitable portion of the polyethylene covering could be replaced with glass or with clear vinyl plastic. The chamber has proved to be an effective means of maintaining a habitat not usually found in temperate North American greenhouses.

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A Presumable Asplenium Hybrid from Kentucky

THOMAS N. MCCOY

In June 1961 when I was scouting the Kentucky countryside in preparation for the Society's annual fern foray, I found a sterile hybrid *Asplenium* in a small hole on a moist sandstone cliff growing in a clump with four other *Asplenium* species. The mass of roots, about one centimeter in diameter, was so matted that the fronds seemed to have a single source. The clump was sent to Dr. Edgar T. Wherry, who realized that some of the fronds were an apparent new hybrid and identified the others as *A. pinnatifidum, A. montanum, A. trudellii,* and *A. trichomanes.* The clump was predominantly *A. trudellii*. Dr. Wherry suggested that Dr. Warren H. Wagner, Jr. see the new hybrid. Dr. Wagner wrote that the plant might be "derived from the gametes of *Asplenium* × *trudellii* (3× 'apogamous') and *A. pinnatifidum* (2× sexual) and therefore, a pentaploid of the constitution MMR × MR = MMMRR." This, of course, has not been proved in the laboratory. I propose the following formula for this plant:

ASPLENIUM **pinnatifidum × trudellii**, hybr. nov. Plate 16

Fronds clustered, 16–21 cm long; stipes brownish-black at base; rhachises green; blades slightly longer than the stipes, lanceolate, somewhat caudate, pinnate at base; basal pinnae decidedly slender-stalked; 4 or 5 suprabasal pinnae adnate at base, ascending; blades merely pinnatifid distally, caudate-serrate at apex; pinnae mostly opposite, deltoid-oblong to acuminate, variously lobed, crenate to serrate; sori near the midrib; spores aborted.

The specimen data are: Cumberland Falls State Park, Kentucky, on a shaded sandstone cliff, June 12, 1961, *Thomas N. McCoy* (US).

To distinguish this hybrid from either of its putative parents is somewhat of a problem. Some characteristics are common to both parents and the hybrid: the stipes are brownish-black at the base, but the remainder of the stipe and rhachis is green, and the fronds are lanceolate. But pinna shape and attachment are different in the three. The pinnae of *A. trudellii* are ovate and long-stalked. In *A. pinnatifidum* the pinnae are rounded and adnate or broadly

ASPLENIUM PINNATIFIDUM × TRUDELLII

stalked. In *A. pinnatifidum* × *trudellii* the pinnae are definitely oblong and have stalks of intermediate length. In addition, there are more free pinnae than in *A. trudellii*, and the pinnae are more distant than those of either parent.

MURRAY, KENTUCKY 42071.

The Correct Name of a Common Tropical American Oleandra

C. V. MORTON

One of the commonest and most widespread Oleandras of the American tropics was long known as *Oleandra nodosa* (Willd.) Presl. When Dr. William R. Maxon (1914, pp. 392–398) published a revision of the American species of *Oleandra*, he used the name *O. articulata* (Swartz) Presl[1] for the species previously known as *O. nodosa*. This was a most confusing change, for *O. articulata* had previously been applied to a common species of tropical Africa and the Mascarene Islands. The basis of this name was *Aspidium articulatum* Swartz.[2] Dr. Maxon decided that because Swartz did not cite any specimen but only plate 136 of Plumier's "Tractatus de Filicibus Americanis," he was in fact basing his new species solely on this illustration. This agrees with some of Maxon's other typifications of Swartz' species that Maxon thought were based on the cited illustrations of Plumier, Sloane, or others. But these typifications are incorrect, including the typification of *Aspidium articulatum* Swartz, which is based on a specimen from the Mascarene Islands. Thus the name *Oleandra articulata* should be restored for the African plant and not used for the American species.

In Schrader's Journal of Botany (1801) Swartz gave brief diagnoses of many new species without citing any specimens. In

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[1] Tent. Pterid. 78. 1836.

[2] J. Bot. Schrad. **1800**(2): 30. 1801.

order to decide the types of these species it is necessary to go to Swartz' "Synopsis Filicum" (1806), where the 1801 diagnoses are repeated but with amplified descriptions and citation of specimens. One has to decide by consultation with Swartz' herbarium at Stockholm which of these specimens he had seen and which were cited from the literature. Naturally, the lectotypes must be specimens that Swartz saw and not literature citations.

Carl Christensen (1910) made a special study of the ferns of the Swartz Herbarium and discussed the typification of many species of Swartz. He made the statement (p. 5, translated):

> "Swartz certainly did not base the new species in his *Synopsis Filicum* on the illustrations of older workers, as did Linné and later Willdenow and others to a great extent. If he cited Sloane, Plumier, Plukenet or others under his species it is certainly always because he believed that his plant corresponded with the cited plate. It is therefore wrong to take up the cited figures as the types of Swartz' species. The type is a specimen, which in most cases is to be found in the Swartz Herbarium."

This statement is of great importance for the typification of *Aspidium articulatum* Swartz.

Since Swartz apparently did not base new species solely on Plumier illustrations, then he must have had a specimen, and there is in fact a specimen in the Swartz Herbarium with the name *Aspidium articulatum* on it apparently in Swartz' own hand. This specimen is from the "Insula Franciae," i.e., Mauritius, collected by Commerson. In the "Synopsis Filicum" Swartz cited the Plumier illustration and "Insula Franciae." Dr. Maxon quotes Lindman as saying that there is no evidence that Swartz had this specimen in hand in 1801, but on the other hand there is no evidence that he did not. It is true that this specimen now has no rhizome, and Swartz described the rhizome. The rhizome could have been lost during the passage of a century, or more likely Swartz drew his description of the rhizome from the Plumier illustration. In the description of the fronds Swartz (1806, p. 236) corrected the original "ellipticis" to "lanceolatis."

That Swartz had a specimen from Mauritius which he identified with a Plumier illustration of a plant from Martinique is not strange. Such a distribution would not have seemed unlikely to Swartz, for in his time many plants from the Mascarene Islands were also attributed to the West Indies. The description was drawn apparently from both the plant and the illustration cited. Specimens can almost always be accurately identified by careful study, but Plumier illustrations seldom if ever can, except by inference from the localities and the generalized descriptions and drawings. In such a case the actual specimen should be chosen as lectotype. I have not seen this type specimen in Stockholm, but I have seen two fine isotypes in the herbarium in Copenhagen. These were received from Jussieu and bear the name *Polypodium articulatum* Juss., which is based on *Aspidium articulatum* Swartz.

Therefore, the name *Oleandra articulata* (Swartz) Presl should be used again for the plant of Mauritius, Réunion, the Seychelles, and tropical Africa, a synonym being *O. distenta* Kunze. Additional synonymy is given by Alston (1959, p. 52). The tropical American species that has been called *O. articulata* in recent years should again be called *O. nodosa* (Willd.) Presl. Its basionym, *Aspidium nodosum* Willd., was based wholly on *plate 136* of Plumier's "Tractatus," the same plate cited by Swartz.

A variety recognizable by its ciliate, glandular-surfaced fronds is:

OLEANDRA ARTICULATA (Swartz) Presl var. **annetii** (Tardieu) Morton, comb. nov.

Oleandra annetii Tardieu, Notul. Syst. **14**: 332. 1952. TYPE: Mont Finde, Cameroun, *Annet 332* (P).

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Vegetative Reproduction in the Ferns I.
Leaf Buds of Grammitis tenella

RICHARD A. WHITE[1]

Morphogenetic studies have shown that the developmental response of ferns to experimental treatment is very broad (see Cutter, 1965). Particularly the early surgical experiments on intact plants (Wardlaw, 1952) indicated how plastic the meristematic areas are. This work has become the basis of more refined experiments, including sterile culture and microsurgical techniques. One of the more recent experiments on intact plants showed that even cells of the petiole of *Dryopteris*, which were presumably mature and fully differentiated, could be caused to become meristematic (Cutter and Wardlaw, 1963). Surgical isolation of patches of cells permitted new meristems to develop and eventually well organized plantlets formed on the petioles of the experimental plants. The natural occurrence of vegetative buds on the various organs of the fern sporophyte is well known (McVeigh, 1937; White, 1968).

While sampling young fern sporophytes for comparative studies of the vascular tissue, I found several leaves of *Grammitis tenella* Kaulf. which had become detached from the parent plant, touched the soil, and developed outgrowths from one surface. These outgrowths, which were in various stages of development, are capable of forming new plants. The development of these buds on mature leaves is unusual and is a new instance of vegetative reproduction for the ferns.

MATERIALS AND METHODS

I collected spores of *Grammitis tenella* on a field trip to the Hawaiian Islands in the summer of 1964. In the laboratory, the spores were surface sterilized in a 10% sodium hypochlorite solution, rinsed in sterile distilled water, and sown, under sterile conditions, on nutrient agar in petri dishes. After the initiation

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[1] This research was supported by National Science Foundation Grants GB-2279 and GB-5454. The technical assistance of Messrs. L. Conde and H. Hutchinson is gratefully acknowledged.

of young sporophytes, the agar with the sporophytes was transferred to soil in pots. The pots were placed in the greenhouse on benches over which cloth screens had been placed to reduce light; an automatic water spray system provided a fine mist which maintained a high humidity level around the plants. Some 200 species of ferns have been grown successfully with this technique.

Pictures of the unusual leaves were taken with a single lens reflex camera prior to preparing them for microscopic study. The specimens were killed and fixed in Navashin solution (CRAF), embedded, sectioned, stained, and prepared for microscopic study in the usual manner. Stained sections were photographed with a 35 mm Leitz Ortholux camera. For comparative purposes, leaves of a normal plant and the thallus of a normal *Grammitis* gametophyte were sectioned and stained.

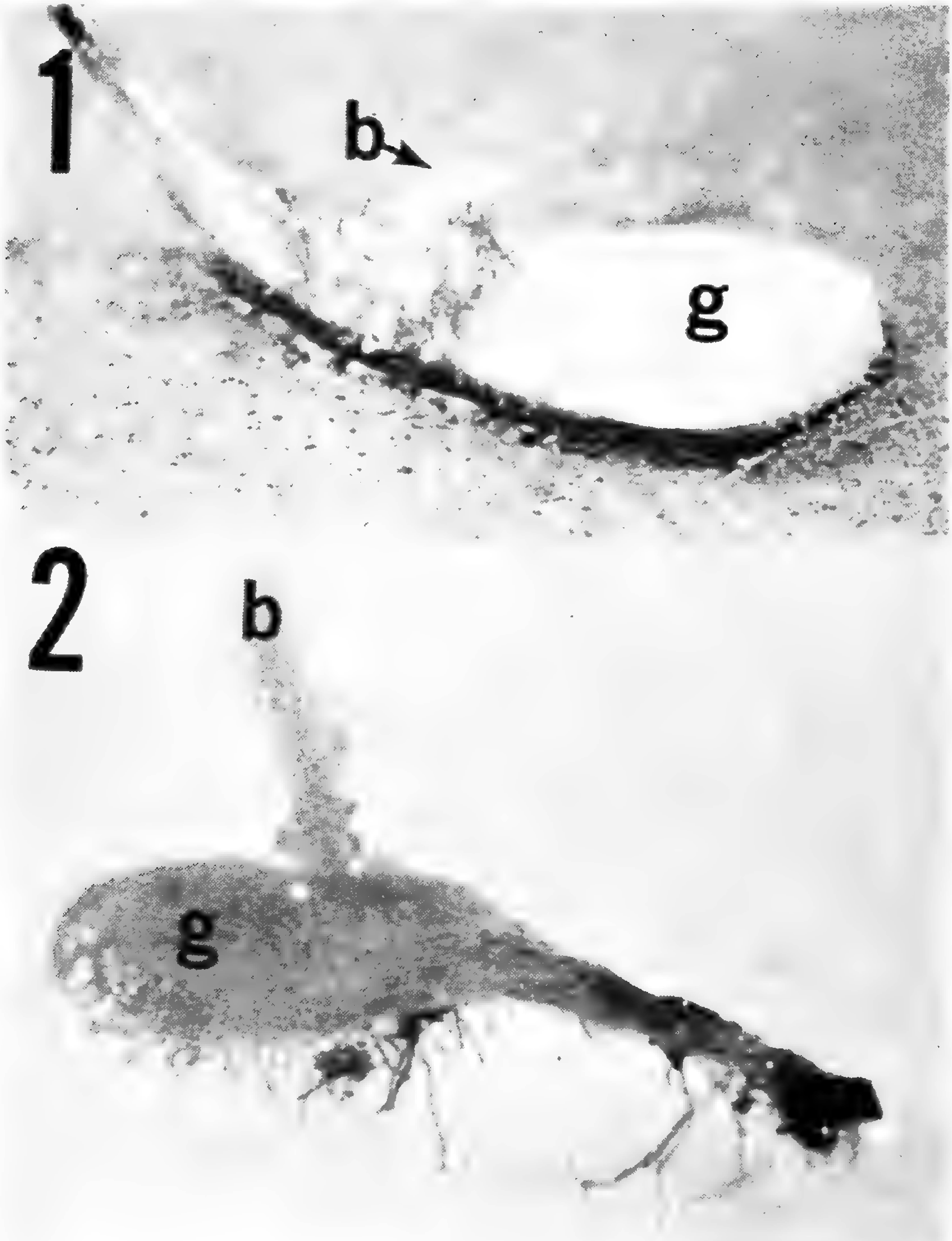
NORMAL GAMETOPHYTES AND LEAVES

Because vegetative reproduction might replace the normal sexual life cycle in this plant, I sectioned several gametophytes to confirm that both antheridia and archegonia occur. Water mounts of living gametophytes revealed swimming sperms. Finally, sporophytes were found still attached to their gametophytes. Sexually-produced sporophytes were initiated 40–60 days after spores were sown on agar, and developed normally.

The leaf anatomy of a normal plant of *Grammitis tenella* is that of a typical fern. Compact palisade parenchyma and spongy parenchyma with numerous air spaces compose the bulk of these small leaves. Both leaf surfaces have a distinct epidermis, and the lower leaf surface typically contains more stomata than the upper. One main vein extends the length of the leaf; small laterals branch from it at intervals. In the upper epidermis bulliform cells are usually associated with the vein endings. Leaf curling in a dry atmosphere is probably caused by these cells.

LEAF OUTGROWTHS

Twelve samples of leaf buds of *Grammitis tenella* in various stages of development were prepared for study. The outgrowths



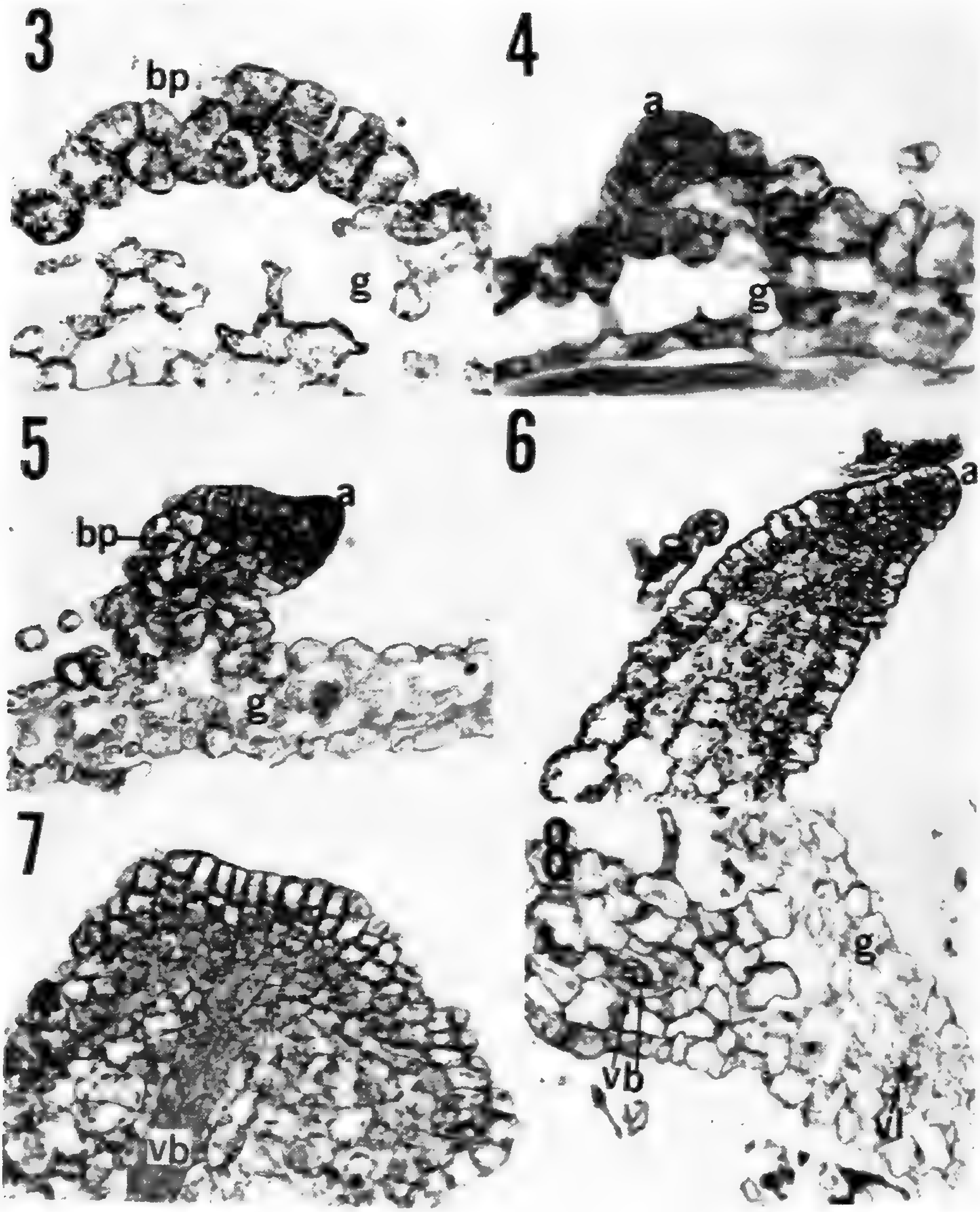
ADVENTITIOUS BUDS FROM LOWER SURFACE OF GRAMMITIS LEAF. FIG. 1. OUTGROWTH WITH STEM MORPHOLOGY, ×5. FIG. 2. TYPICAL OUTGROWTH WITH LEAF MORPHOLOGY, ×5.

always occur on the lower (abaxial) leaf surface, which is the one with the most stomata, the one most closely associated with the spongy parenchyma tissue, and the one toward which the phloem is found in the main vein as seen in cross section of the leaf (*Figs. 1* and *2*). When leaves fall from the plant, buds develop only in those that land with the abaxial leaf surface up. No buds grew into the soil from the adaxial leaf surface, nor when the abaxial surface was down.

Cell divisions first occur in the previously mature epidermal cells of the adaxial leaf surface. Rhizoids develop and are cut off from the epidermal cells by cell walls. Hairs or scales also may develop from previously mature epidermal cells surrounding the area in which the bud will form.

Initiation and development of the outgrowth continues with divisions of the parenchyma cells just below the abaxial epidermal cells (*Fig. 3*). The epidermis bulges at first, but subsequent development involves the epidermal cells, for no mechanical breaks occur in this layer (*Figs. 4* and *5*). As cell divisions continue, the meristematic mass becomes three dimensional and rounded (*Fig. 5*), and usually develops into a leaf primordium (*Fig. 6*). The single apical cell and its orientation to the surrounding cells of the primordium is similar to that found in many young fern leaves. By continued division and elongation of the meristematic cells, the outgrowth increases in size considerably (*Figs. 6* and *7*). Following the initial increase in size, typical leaf flattening occurs. Stomata are present on both surfaces. The venation pattern in paradermal section is typical of mature *Grammitis* leaves (*Fig. 7*).

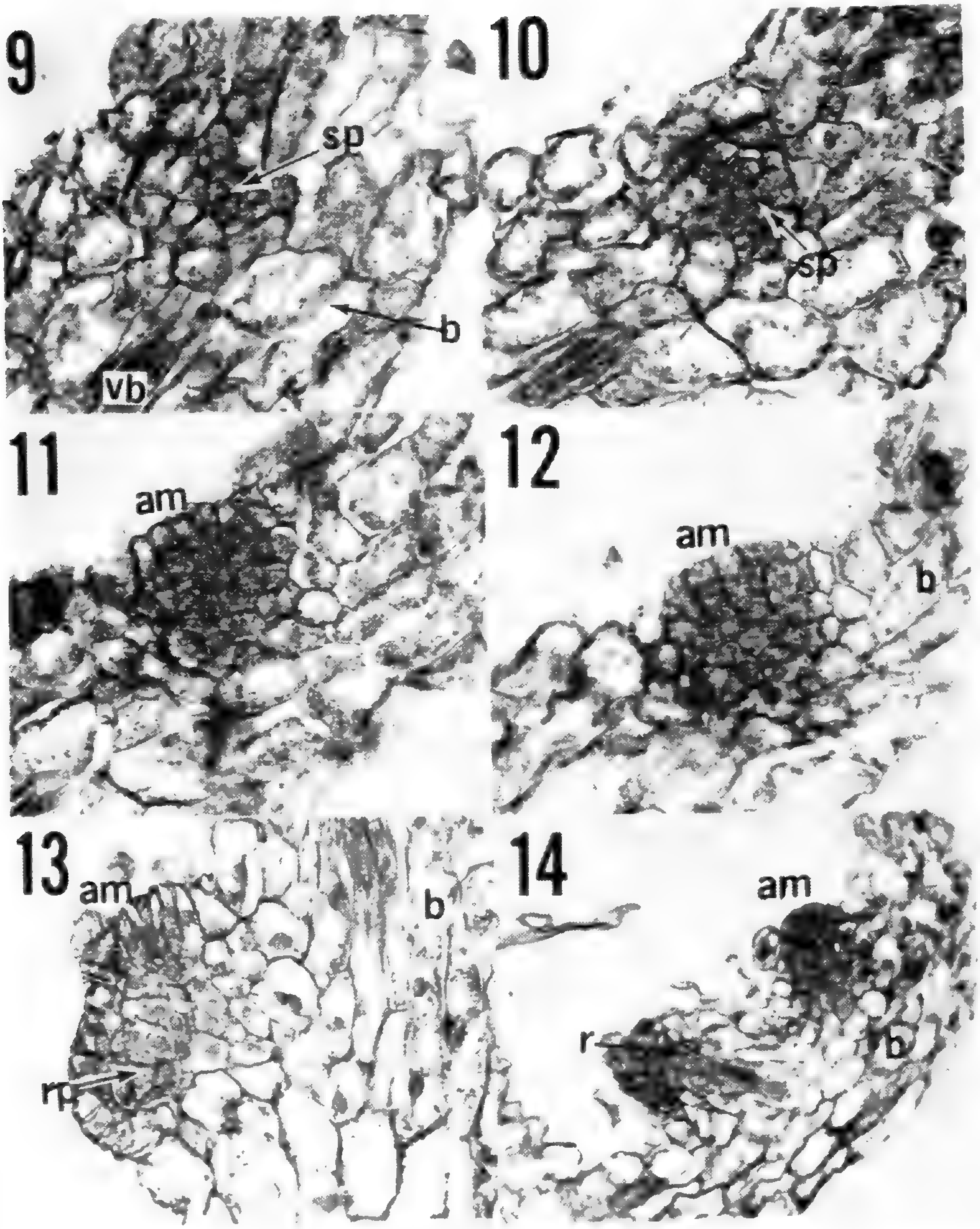
Very young primordia are composed of solid parenchyma; there is no evidence of provascular tissue. Following the formation of a distinct apical cell, however, provascular tissue differentiates (*Fig. 7*). Cells just above the connection between the outgrowth and the parent leaf surface divide and stain differentially. As development of the new leaf continues, a vascular strand extends upward toward the primordium tip from an early-formed vascular nodule in the base of the leaf (*Fig. 8*). Vascular differentiation



Histological Detail of Leaf Bud Development. Fig. 3. Origin of outgrowth in superficial parenchyma of abaxial leaf surface, ×195. Fig. 4. Apical organization in young primordium, ×190. Fig. 5. Bud primordium with well-organized meristem, ×95. Fig. 6. Median longisection of outgrowth with typical apical cell, epidermis and parenchyma, ×190. Fig. 7. Paradermal section of outgrowth through parenchyma and vascular strand, ×115. Fig. 8. Attachment of out-occurs in an acropetal direction from this nodule toward the leaf tip. There is no connection between the vascular system of the outgrowth and that of the parent leaf (*Fig. 8*). As the new outgrowth continues to grow and elongate, cells at the base of the outgrowth become meristematic. Usually these cells are located where the outgrowth connects to the abaxial leaf surface. A bud primordium originates by divisions in the parenchyma surrounding the vascular strand (*Figs. 9* and *10*). The initiation of cell divisions here causes renewed cell division in surrounding cells, and the primordium increases in size (*Fig. 11*). An apical meristem is organized just before the bud emerges from the surface of the outgrowth. Apical cell morphology is typical of the shoot apices of most polypodiaceous ferns and is very similar to that found in the *Grammitis* sporophyte (*Figs. 11–13*). After a shoot meristem is organized root initials differentiate in the bud primordium (*Fig. 13*). As in the development of lateral roots on most fern stems, each root develops endogenously in shoot tissue, and generally at least one root is associated with each leaf that is produced at the shoot apex.

Following the development of a functional apical meristem, internal vascular tissue differentiation takes place. In contrast to the lack of vascular continuity between the outgrowth and the parent leaf, the shoot meristem is connected with the vascular strand of the outgrowth (*Figs. 9, 10,* and *14*). Although the first provascular tissue develops in the newly formed shoot meristem area, further differentiation of xylem is acropetal and proceeds from the vascular strand of the outgrowth into the meristem of the new shoot primordium. A single vascular strand connects the

GROWTH AND LEAF WITH VASCULAR STRAND OF OUTGROWTH AND VEIN OF PARENT LEAF UNCONNECTED, ×115. The abbreviations are: *a*, APICAL CELL; *am*, APICAL MERISTEM OF SHOOT; *b*, ADVENTITIOUS BUD; *bp*, ADVENTITIOUS BUD PRIMORDIUM; *g*, GRAMMITIS LEAF; *r*, ROOT; *rp*, ROOT PRIMORDIUM; *sp*, SHOOT PRIMORDIUM; *vb*, VASCULAR TISSUE OF BUD; *vl*, VEIN OF GRAMMITIS LEAF.



Histological Detail of Shoot Formation. Fig. 9. Origin of new shoot primordium in parenchyma associated with vascular tissue of the adventitious outgrowth, ×680. Fig. 10. Additional mitotic divisions in shoot primordium. ×200. Fig. 11. Apical meristem of shoot primordium. ×200. Fig. 12. Development of root primordial initials, ×200. Fig. 13. Distinct apical and root meristems on endogenous bud, ×200 Fig. 14. Organized adventitious bud with shoot and root meristems. ×100. The abbreviations are identical to Plate 18.

vascular tissue of the leaf outgrowth to that of the developing bud.

One sample differed in its later stages from the pattern of development described above. In contrast to the others it developed and maintained radial symmetry, and morphologically appeared to be a stem rather than a leaf. In addition to radial symmetry, there were few stomata present on the surface of the outgrowth and there was a simple, single, central vascular strand. Careful analysis of the vascular strand revealed mesarch xylem differentiation. At the tip of this stem-like outgrowth, a flange of tissue differentiated which had obvious leaf-like characters: stomata primarily on one surface, dorsiventral flattening, a simple large terminal apical cell, and branched venation. Groups of cells which stained differentially occurred where the leaf-like flange was attached to the radially symmetrical outgrowth. These meristematic cells developed into a bud primordium similar to those described previously which occur where the outgrowth is attached to the parent leaf. As in the other samples, a simple vascular strand connected the meristematic area with the vascular strand of the outgrowth. In addition to the hairs or scales which had developed from the parent leaf surface, appendages similar to root hairs developed from the surface cells of the outgrowth at the point of attachment to the parent leaf.

DISCUSSION

The development of buds in *Grammitis tenella* from the abaxial surface of mature leaves which have come in contact with soil or other suitable substrate appears to be unique in the ferns. In most instances of plantlet formation from fern leaves, bulbils are present on the leaves of intact plants (Marchal, 1965) or the culture conditions are more harsh (Morlong, 1967). Gametophytic outgrowths occur in other cases of detached fern leaves growing under conditions similar to those described for these leaves.

Development of leaf outgrowths in *Grammitis* involves considerable dedifferentiation of mature parenchyma cells. Mature cells which compose the spongy mesophyll of the mature leaf first become meristematic. Epidermal cells of the adaxial leaf surface undergo renewed cell division to form rhizoid-like structures similar to those found on typical fern gametophytes. Epidermal cells of the abaxial leaf surface also undergo renewed cell division and form scales and hairs which surround the developing bud.

On the basis of the developmental stages noted in this study, the initial outgrowth from the mature sporophytic leaf is usually a leaf. The apical organization, dorsiventral flattening, stomatal arrangement, and vascular pattern of these outgrowths support this conclusion. Interestingly, vascular differentiation in the outgrowth does not occur until a typical leaf apical cell is formed. Subsequent to the formation of the apical cell, xylem differentiation begins in the outgrowth and appears to proceed under its control. In contrast to previous reports of adventitious buds on other fern leaves (Marchal, 1965), in *G. tenella* no connection is ever made between the vascular strand of the parent leaf and the vascular tissue of the lateral outgrowth.

Organized stem and root meristems develop after the apical cell of the leaf-like outgrowth has formed. Thus, in addition to vascular differentiation, the initial organization of the new shoot meristem at the base of the outgrowth probably is under the control of the apical cell also. The morphology and development of the shoot meristem, which is at the juncture of the outgrowth with the parent leaf, is very similar to that of a typical axillary bud. The histogenesis of this bud is very similar to that of many normal axillary buds in other ferns (e.g. *Marsilea*, White, 1966). Eventually it forms young leaf primordia in addition to the main stem apex, and one to several young adventitious root primordia may form also. Since the location of the meristem on the outgrowth is not in the leaf axil, it is not truly an axillary bud.

In one sample, the morphology of the outgrowth indicates it was basically a stem. The organ was radially symmetrical, had few stomata, and the xylem differentiation pattern in the axis was mesarch. Interestingly, the terminal portion of this outgrowth developed a flattened flange of tissue which was leaf-like in its venation pattern, stomatal arrangement, and terminal meristem organization. In this case, the new shoot meristem differentiated at the juncture of the flange with the radially symmetrical outgrowth. If the radially symmetrical outgrowth is a stem, this one case would be an example of true axillary bud formation. The possibility cannot be discounted, however, that the radially symmetrical outgrowth is a leaf petiole, with the flange equivalent to a leaf blade. The distance of the new shoot meristem from the juncture of the outgrowth and the parent leaf was different for each of the samples. This is somewhat similar to that described by Wardlaw (1949) for "detached meristems" with reference to the variation in location of normal axillary buds. If the radial outgrowth is a petiole rather than a stem, the shoot meristem is not an axillary bud. It would be merely a displaced meristem and, except for its location, similar to the other samples described here.

Based on all the data, the simplest explanation is that a primordial leaf develops from the abaxial surface of a detached mature sporophyte leaf. The vasculature of this appendage and a new shoot meristem are both differentiated under the influence of the apical cell of this developing leaf. The shoot meristem, although not axillary to a stem, has all the morphological and developmental characteristics of a true axillary bud.

In the one case where an outgrowth grew successfully to maturity, the initial leaf-like outgrowth did not develop substantially, but rather the shoot meristem continued to grow and develop additional young leaves and roots. Eventually the parent leaf shrivelled and disintegrated, while the new plant grew to maturity and bore viable spores.

In the dense, rainy areas of Hawaii where these plants were collected, it is conceivable that such a method of asexual reproduction could be of some benefit to the plant. Although obviously not contributing to genetic variability, it would establish populations of the species. My general collections of the fern were always of large clusters of plants of various ages. A careful survey of four large preserved collections of this species from two trips to Hawaii revealed only six leaves that had small flanges on them. The leaf outgrowths generally are very fragile, and several of those found in the greenhouse pots were destroyed by rough handling. My collections usually were of the larger, more easily seen plants, and were pressed tightly into bottles of FAA, possibly precluding the preservation of very many useful or recognizable outgrowths. The leaf budding phenomenon that I found in the laboratory may occur in nature, but more careful observations and field collections are called for.

The natural development of whole young plants from previously mature and differentiated cells adds further support to the results of experimental studies previously carried out on intact plants (Wardlaw, 1952; Cutter and Wardlaw, 1963). The potentials for differentiation and development that have been elucidated through experimental morphological techniques appear in this instance to have been realized in nature also. The problem of the physiological control of the development of these leaf outgrowths in *Grammitis* remains to be solved. A preliminary investigation into this question is to begin shortly (C. W. Smith, Univ. of Hawaii, pers. comm.).

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Taxonomic Revision of the Polypodiaceous Genera of India—III. Pleopeltis

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Pleopeltis Humb. and Bonpl. ex Willd. is mainly a tropical American fern genus. Most of the species described in this genus from the Indian region by Beddome (1863–65?, 1892) have now been transferred to other polypodiaceous genera such as *Lepisorus* (J. Smith) Ching, *Microsorium* Link, *Phymatodes* Presl, *Colysis* Presl, and *Arthromeris* J. Smith.

Copeland (1947, p. 183) circumscribed *Pleopeltis* so as to include *Lepisorus*, which was recognized earlier as an independent genus by Ching (1933, 1940, p. 258), Christensen (1938), and Holttum (1946, 1954). Sledge (1960) and Panigrahi and Patnaik (1964, 1965), however, followed Copeland in uniting these two genera. Ching (1933) recognized and redefined *Lepisorus* to include the Asiatic species that had been placed in *Pleopeltis*, while maintaining the latter as a New World genus. We have followed Ching and Christensen in treating the two genera as distinct, but consider *Pleopeltis* to be present in the Old World also. The species of *Lepisorus* do not belong in *Pleopeltis*, although they are greatly similar in frond outline and sorus shape and position. Christensen (1938, p. 547) described the scales of *Lepisorus* as "often clathrate" and those of *Pleopeltis* as "non clathrate," but according to Copeland, this distinction is not tenable; the scales of both genera are distinctly clathrate. However, there is a definite difference in scale distribution on the under surface of the lamina. In *Lepisorus* only the midrib is scaly, whereas the under surface of *Pleopeltis* fronds is uniformly covered with peltate, orbicular-lanceolate, appressed, usually fimbriate scales. This difference is very constant in the Indian species.

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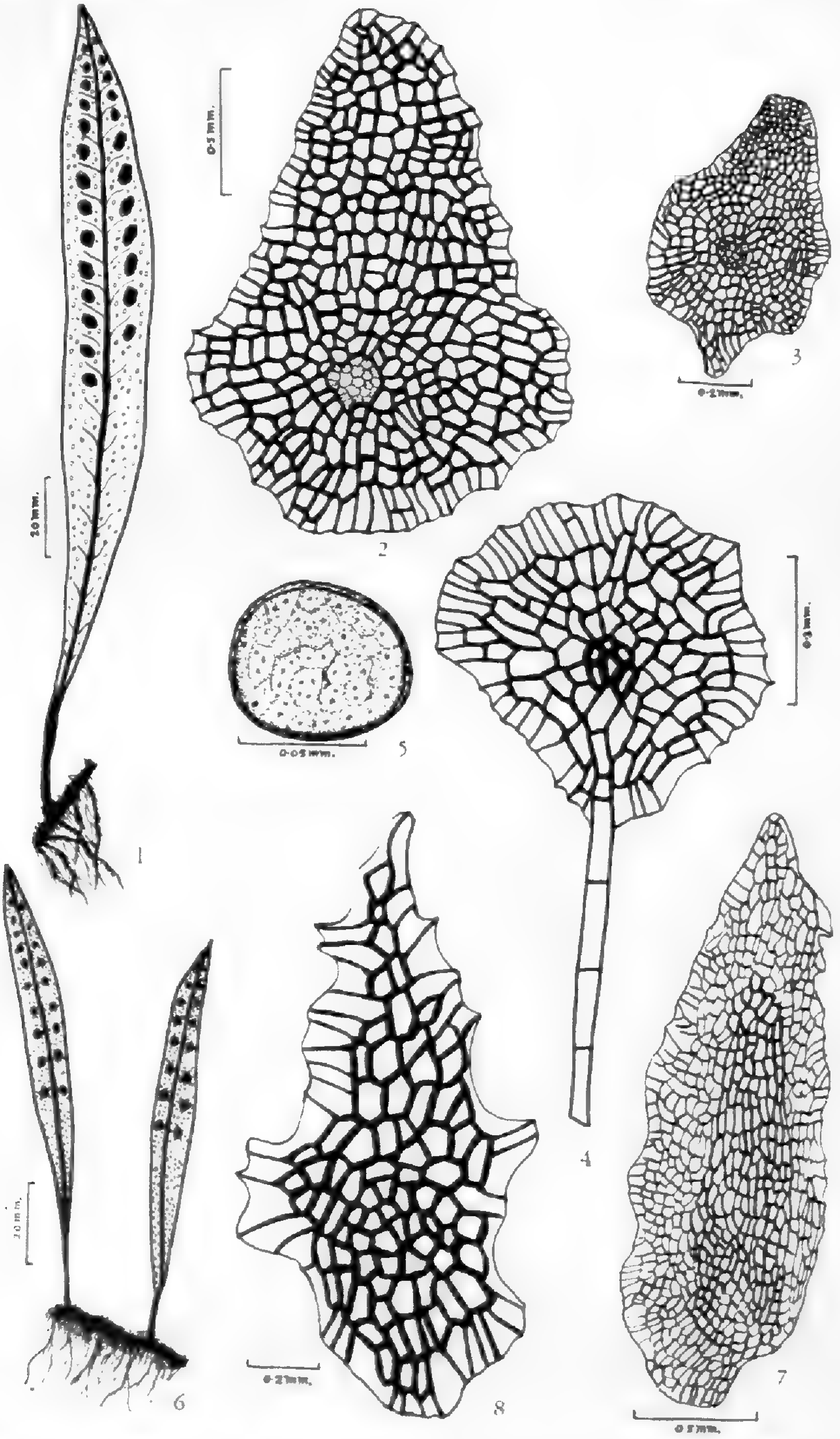
[1] Our grateful thanks are due C. V. Morton and D. B. Lellinger for valuable suggestions and helpful criticism, Prof. P. N. Mehra for inspiration and encouragement, and to the Keepers or Directors of the cited herbaria for the loan of specimens.



FIGS. 1–5. PLEOPELTIS MACROSPHAERA VAR. ASTEROLEPIS. FIG. 1. HABIT SKETCH. FIG. 2. RHIZOME SCALE. FIG. 3. FROND SCALE. FIG. 4. SPORANGIAL PARAPHYSIS. FIG. 5. SPORE. FIGS. 6–8. P. MACROCARPA. FIG. 6. HABIT SKETCH. FIG. 7. RHIZOME SCALE. FIG. 8. FROND SCALE.

PLEOPELTIS Humb. & Bonpl. ex Willd. in L. Sp. Pl., ed. 4, **5**: 211. 1810.

Rhizome wide-creeping, paleate; fronds articulated to the rhizome, uniform or slightly dimorphic, simple or rarely pinnatifid, entire, coriaceous, bearing peltate, clathrate, appressed paleae on the under surface; veins anastomosing freely and irregularly with included veinlets; sori uniseriate on either side of the midrib, polypodioid, typically round, elliptic, or suborbicular, rarely confluent, protected at least in young stages by peltate paraphyses with flat, expanded heads; spores bilateral, nonperisporiate, smooth or nearly so.

The only Asiatic species are *P. macrocarpa* (Bory ex Willd.) Kaulf. and *P. macrosphaera* (Baker) Panigr. & Patn., both of which are recorded from India. Specimens of these have commonly been placed in *Polypodium* or lately in *Lepisorus*.

KEY TO THE SPECIES OF PLEOPELTIS

Sori submarginal or nearly so........................ 1. *P. macrosphaera*

Sori medial or near the midrib.

  Laminae 1.5–3 cm broad............ 1a. *P. macrosphaera* var. *asterolepis*

  Laminae 1.5 cm broad or less........................ 2. *P. macrocarpa*

1. PLEOPELTIS MACROSPHAERA (Baker) Panigr. & Patn. Proc. Nat. Acad. Sci. India, B, **34**: 481. 1964 var. MACROSPHAERA.

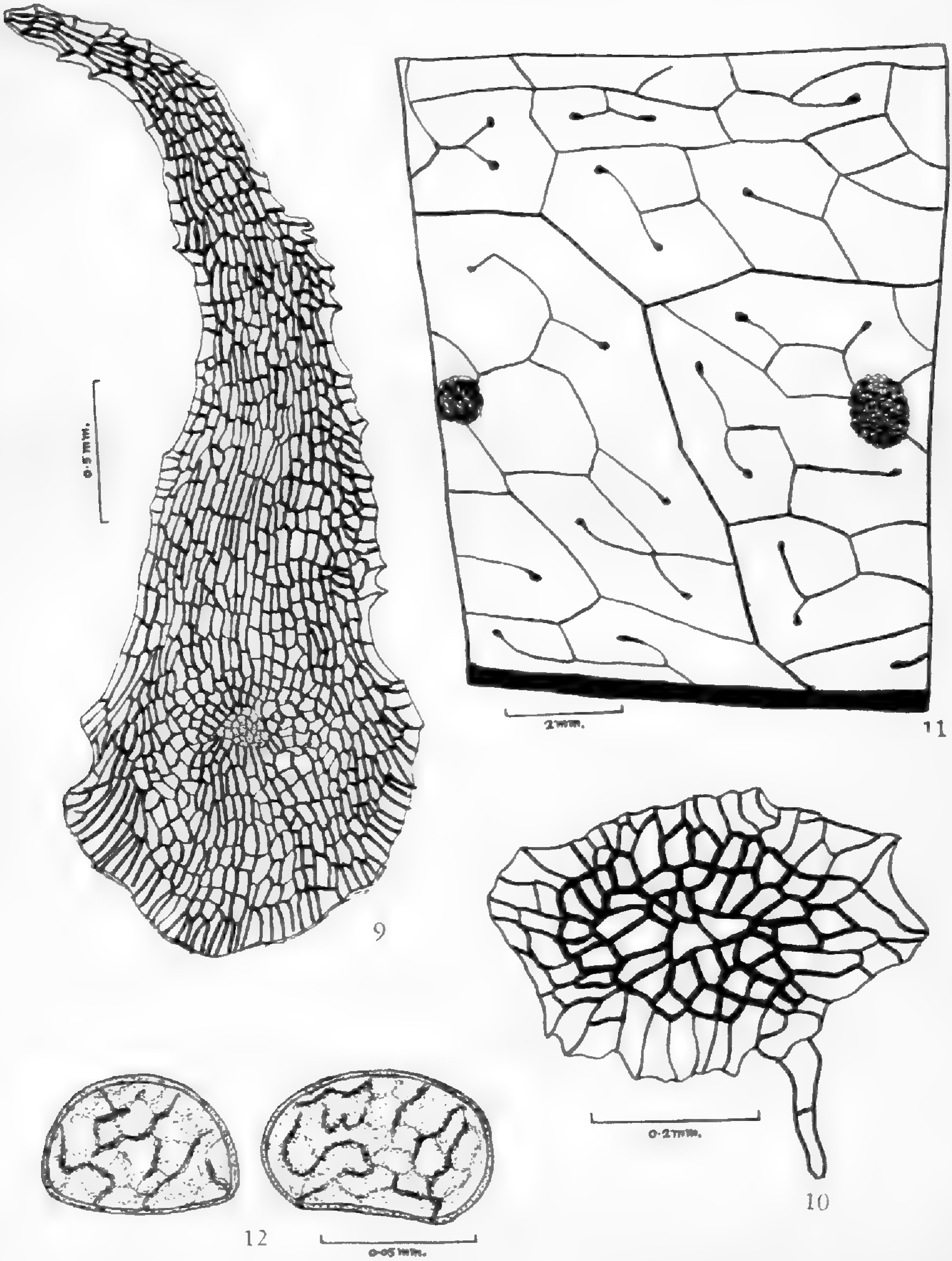
Polypodium macrosphaerum Baker, Kew Bull. **1895**: 55. 1895.

Polypodium intramarginale Baker in Christ, Bull. Herb. Boiss., II, **3**: 509. 1903.

Lepisorus macrosphaerus (Baker) Ching, Bull. Fan Mem. Inst. Biol. **4**: 73. 1933.

Rhizome rather thick, creeping, epigaeous, naked except at the growing tip and stipe bases, these sparsely scaly; scales brown, thin, concolorous, ovate, obtuse, dorsally affixed, deciduous, nearly entire, the cell lumina medium-sized, uniform, clear; fronds rather distant, 30–50 cm long, up to 3 cm broad, linear-lanceolate; stipes long, terete, naked; laminae glabrous or more often scaly beneath when young, coriaceous, greenish; venation prominent; sori large, oblong, submarginal or sometimes medial.

DISTRIBUTION: Eastern Himalayas (Khasya, *C. B. Clarke 43627A*) and China, according to Ching (1934, text accompanying *pl. 62*). Also known from a recent collection at Subansiri, Forest Division, North East Frontier Agency, *Panigrahi 19858* (ASSAM).



FIGS. 9–12. PLEOPELTIS MACROCARPA. FIG. 9. RHIZOME SCALE. FIG. 10. SPORANGIAL PARAPHYSIS. FIG. 11. VENATION. FIG. 12. SPORE.

The chief characteristics of this fern are the concolorous ovate-obtuse, entire scales, the submarginal sori, and the long, naked, terete stipes. In sorus position it is easily confused with *Lepisorus loriformis* (Wall. ex Mett.) Ching, which can be distinguished by the lack of scales on the under surface of the lamina.

1a. PLEOPELTIS MACROSPHAERA var. ASTEROLEPIS (Baker) Panigr. & Patn., Proc. Nat. Acad. Sci. India, B, **34**: 482. 1964. *Figs. 1–5*

Polypodium asterolepis Baker, J. Bot. Brit. & For. **26**: 230. 1888.

Fronds lanceolate-acuminate, 24–30 cm long, 1.5–3 cm broad, sparsely scaly all over beneath, more coriaceous than var. *macrosphaera*, often yellowish; venation completely immersed; sori oblong, oblique, medial; spores bright brown, reniform or plano-convex to concavo-convex, the exine slightly thick and granulated, 48–64 μ × 38–45 μ.

DISTRIBUTION: Eastern Himalayas (Assam and Manipur State), Burma, and China.

This fern is closely similar to *Lepisorus excavatus* (Bory) Ching in frond outline, but is distinguished by hidden venation and a scaly under surface. From var. *macrosphaera* it is distinguished by its broad fronds with medial sori.

SPECIMENS EXAMINED: **Eastern Himalayas:** Assam, Manipur State, Kangpokpi, Feb. 1940, *Fleming* (US). **Burma:** Taunggyi, Shan States, April 1938, *Dickason 9244* (US); Haka, Chin Hills, alt. 1890 m, April 1938, *Dickason 7418* (US).

2. PLEOPELTIS MACROCARPA (Bory ex Willd.) Kaulf.,[2] Berlin. Jahrb. Pharm. **21**: 41. 1820. *Figs. 6–12*

Polypodium lanceolatum L., Sp. Pl. **2**: 1082. 1753.

Polypodium macrocarpum Bory ex Willd. in L., Sp. Pl. ed. 4, **5**: 147. 1810.

Polypodium marginale Bory ex Willd. in L., Sp. Pl., ed. 4, **5**: 149. 1810, *non* L. 1753, *nec* Thunb. 1784.

Pleopeltis marginalis (Bory ex Willd.) Kaulf., Berlin. Jahrb. Pharm. **21**: 41. 1820, *non* Kaulf. 1824.

Pleopeltis lanceolata Kaulf. Enum. Fil. 245. 1824.

Pleopeltis linearis Kaulf., Enum. Fil. 245. 1824.

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[2] Christensen (1905–06, p. 500) and Sledge (1960) gave this reference as *P. macrocarpa* (Willd.) Kaulf. Enum. Fil. 245. 1824, which is wrong according to Pichi-Sermolli (1965). This binomial was validly published for the first time in the "Berlinisches Jahrbuch für die Pharmacie," vol. 21, in 1820. For the nomenclature and complete synonymy see Pichi-Sermolli.

Polypodium lepidotum Willd. ex Schlecht. Adumbr. Pl. **2**: 17, *t.* 7. 1825.
Pleopeltis lepidota (Willd. ex Schlecht.) Presl, Tent. Pterid. 193. 1836.
Pleopeltis lanceolata (L.) Presl, Tent. Pterid. 193. 1836, *non* Kaulf. 1824.

Rhizome widely creeping, branched, paleaceous; scales lanceolate-ovate, ferruginous, mostly dark brown in the center and pale at the margins, 2–3 mm long, 0.5–1 mm wide, appressed, ciliate-denticulate; stipes remote, 2–6 cm long, sparsely scaly; laminae 5–15 cm long, 0.5–1.5 cm wide, linear-lanceolate, the apex more or less acuminate, gradually attenuate at the base, yellowish brown, coriaceous, densely scaly on the under surface, the scales orbicular-lanceolate, dark brown, clathrate, appressed, dentate, sparsely scaly on the upper surface, the scales hyaline at the margin; veins immersed, the primary veins anastomosing to form large, oblique, elongate areolae, these with different-sized secondary areolae with a few, free, simple or rarely forked veinlets; sori large, brown, globose, oval, elliptic, or suborbicular, covered prominently in young stages with umbrella-shaped, clathrate paraphyses; annular cells 11–15; spores yellowish, plano-convex to concavo-convex or reniform, the exospore smooth and slightly thickened, 58–74 $\mu \times$ 38–48 μ.

DISTRIBUTION: South India (in the Nilgiris, Palni, and Shivoroy Hills at 1500–2400 m altitude), Darjeeling, Assam (according to Beddome), Ceylon, Africa, Hawaiian Islands, St. Helena, and the American tropics.

This fern can conveniently be separated from some *Lepisorus* species which it closely resembles, namely, *L. excavatus* (Bory) Ching and *L. nudus* (Hook.) Ching, by both surfaces being paleaceous, the underside rather densely so. This polymorphic species has great variation in frond size and in sorus outline and size. The fertile fronds are often contracted.

SPECIMENS EXAMINED: **Eastern Himalayas:** Darjeeling, Oct. 1958, *Thakur* (CAL). **South India:** Kodaikanal: Shola below Moir point, alt. 2100 m, June 1962, *Bir* (PAN 4713–15)[3]; Nilgiris, alt. 2100 m, May 1886, *Gamble 17328* (US); Balmadies Estate Yercaud, alt. 1666 m, Dec. 1958, *Subramanyan 7553* (MH); Shivoroy Hills, *Perrottet 297* (CAL); Dodabelha, alt. 2400 m, June 1883, *Gamble* (CAL); Aug. 1878, *King* (CAL); Ootacomand, alt. 2250 m, June 1883, *Levinge* (CAL); Ralliah Dam, alt. 2100–2400 m, May 1954, *Sal-*

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[3] The Panjab University Herbarium, Chandigarh, which is not yet included in "Index Herbariorum," is here designated PAN.

danha 1202A (BLAT); Pulney [Palni] Hills, alt. 1260 m, Dec. 1913, *Saulière 422* (US), "Southern Hindustan," *Noyes* (US).

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Trends of Specialization in the Stipe Anatomy of Dennstaedtia and Related Genera

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The scope and position of the dennstaedtioid ferns in the Filicales has varied considerably in systematic treatments. In Bower's (1926, p. 268, 1928, p. 5) system they were included in the Dicksoniaceae in a scheme which separated that family from the Cyatheaceae. Conard (1908) believed that *Dennstaedtia* belonged in the Polypodiaceae, as it was separable from the Cyatheaceae on characters of the annulus, antheridium, and prothallium. Separation of the tree ferns into Cyatheaceae and Dicksoniaceae was maintained by Holttum (1949). He placed the Dennstaedtiaceae in a central position as a large, complex family including 81 genera. Holttum's Dennstaedtioideae was considered the most primitive of 11 subfamilies. Later Holttum and Sen (1961) demonstrated a close relationship between *Cyathea, Dicksonia, Culcita* and *Cibotium* on the basis of the development of the sorus. This removed the main objection to uniting the tree ferns into one family, but *Dennstaedtia* was regarded as belonging to a different group of genera, even though there is evidence of some relationship with the tree ferns. Holttum and Sen (1961) did not attempt to answer whether the above genera should be considered as belonging to subfamilies of a single family or remain as separate families, but Holttum (1963, pp. 71–72) placed them in three subfamilies of the Cyatheaceae.

The stipe anatomy of the dennstaedtioid (including pteroid) and cyatheoid ferns shows greater structural complexity than that of any other extant group of ferns. While some of these stipes have been described in the past (Gwynne-Vaughan, 1901, 1903, p. 721; Bertrand and Cornaille, 1902, p. 47; Conard, 1908; Bower, 1926, p. 264, 1928, p. 5; Holttum and Sen, 1961; Tryon, 1962),

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[1] I wish to express my appreciation to the Organization for Tropical Studies, San José, Costa Rica, for providing financial support and facilities for the conduct of this investigation. Also I am grateful to Drs. W. H. Wagner, Jr., J. T. Mickel, E. de la Sota, D. B. Lellinger, and A. M. Evans for their advice and encouragement.

the characteristics of stipe anatomy have not been utilized comprehensively in taxonomy. The present survey was undertaken to establish the degree of variability and the trends of specialization of this feature. I believe that taxonomically important characters are present.

TABLE I. VOUCHERS AND CHARACTER STATE CHANGES IN DENNSTAEDTIOID AND PTEROID FERNS.

Species	*Voucher number*	*Specialization*[1]
Blotiella lindeniana (Hook.) Tryon	3432	2, 4, 5, 7
Dennstaedtia arborescens (Willd.) Ekman ex Maxon	3111	4
D. bipinnata (Cav.) Maxon	2697, 3505	3, 4, 5
D. cicutaria (Swartz) Moore	3118	1, 4
D. dissecta (Swartz) Moore	2946	3, 4, 5
D. obtusifolia (Willd.) Moore	2947	1, 3, 4
D. spinosa Mickel	2730	4
Histiopteris incisa (Thunb.) J. Smith	3193	2, 7
Hypolepis bogotensis H. B. K.	3248	1, 2, 4, 5
H. pulcherrima Underw. & Maxon	3306	3, 4, 5, 6
H. repens (L.) Presl	2743	2, 4
H. sp.	*s.n.*	2, 4
H. sp.	3428	1, 4, 5
Lonchitis hirsuta L.	2590	2, 3, 4, 5, 7
Loxsomopsis costaricensis Christ	3001	3, 4, 5
Paesia anfractuosa (Christ) C. Chr.	3000	1, 2
Pteridium aquilinum (L.) Kuhn	*s.n.*	1, 2, 4, 5
Pteris altissima Poir. in Lam.	*s.n.*	–
P. podophylla Swartz	3279	2, 4, 5
P. pungens Willd.	3563	3, 4, 5
Saccoloma elegans Kaulf.	2799	1, 5
Saccoloma inaequale (Kunze) Mett.	2755	1, 5

[1] Numbers are of those characters from *Table III* which show the advanced state.

During July and August, 1967, I examined 17 genera and 33 species of ferns in Costa Rica (*Tables I* and *II*). Where vouchers were collected, the collection numbers of John T. Mickel are given. Specimens have been deposited at US. The anatomy of nearly all of the species was checked several times; in no case were there significant variations from the patterns drawn from the cited specimens. Freehand thin sections of stipe bases were prepared from fresh specimens and were examined and drawn under 50× magnification with a dissecting microscope. Particular attention was paid to the anatomy of the vascular trace and to the course of the xylem. Sections made throughout the length of the stipe of many specimens indicated that no fundamental changes take place distally; only a reduction in size occurs as the pinnae are vascularized. To assure uniformity of comparison, all cross sections illustrated are from stipe bases. For several representative genera, preserved material was used to prepare stained microtome sections to confirm details of histology.

TABLE II. VOUCHERS AND CHARACTER STATE CHANGES IN CYATHEOID FERNS.

Species	*Voucher number*	*Specialization*[1]
Alsophila spp.	2795, 3291	1, 2
Culcita coniifolia (Hook.) Maxon	3238	1, 4, 5
Cyathea aureonitens Christ	2948	1, 2
C. maxonii Underw.	*s.n.*	1, 2
Dicksonia gigantea Karst.	3134	1, 2, 3, 6
Hemitelia choricarpa Maxon	2797	1, 2
H. costaricensis (Kl.) Mett. ex Kuhn	2861	1, 2
Lophosoria quadripinnata (Gmel.) C. Chr.	3638	1, 2, 4, 6
Metaxya rostrata (H. B. K.) Presl	2853	1, 3

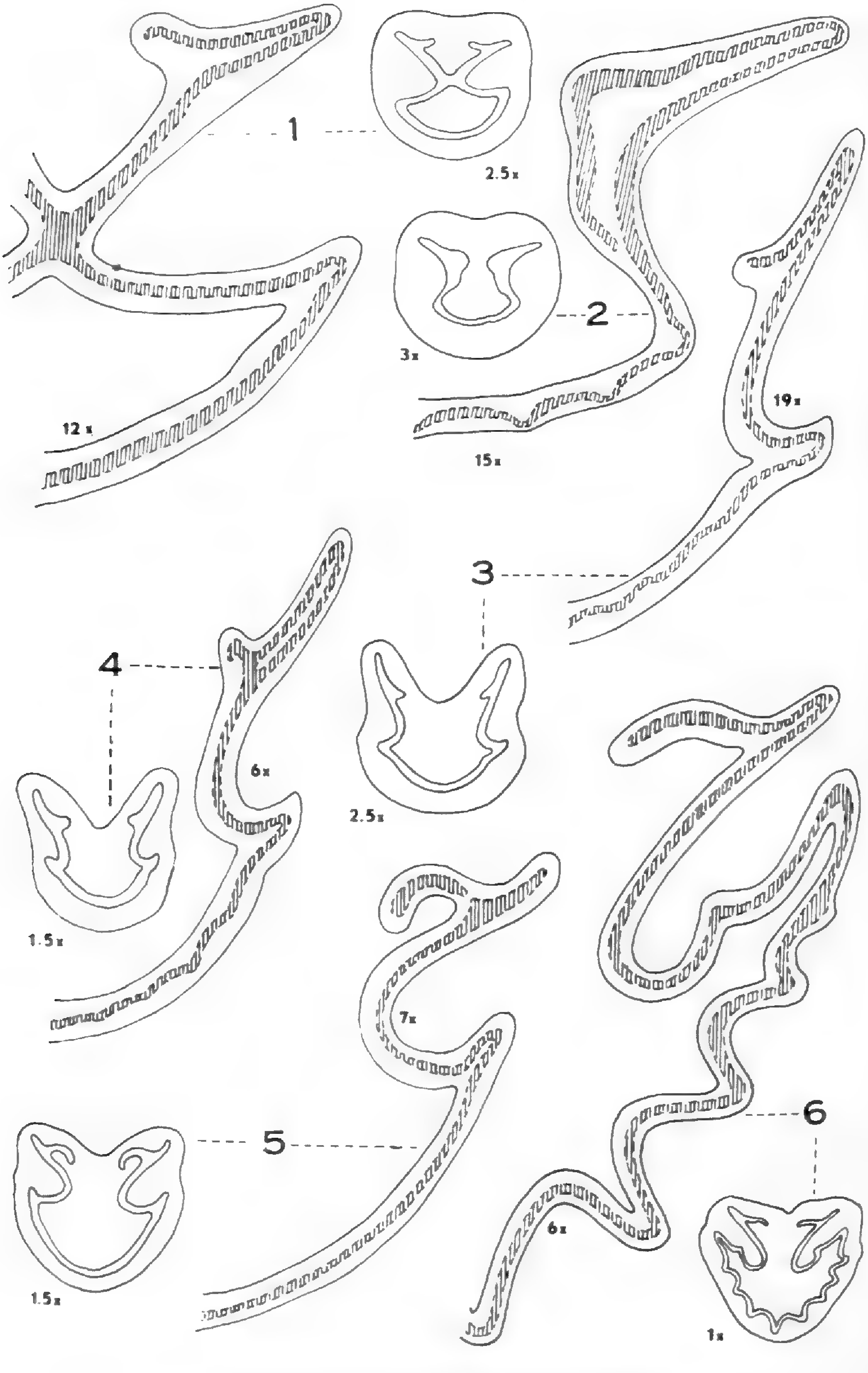
[1] Numbers are of those characters from *Table III* which show the advanced state.

Nearly all of the genera in this investigation have a single adaxial groove on the stipe and rachis. On all specimens the abaxial portion is uniformly convex in outline. The stipes are either convex or slightly grooved laterally. An aeration line is often present in the lateral groove or above it. The stipes contain one or more meristeles each completely surrounded by an endodermis. At the center of the meristele is the xylem, which is one to several cells thick and which is surrounded by layers of parenchyma, phloem, pericycle, and endodermis. More detailed descriptions of the histology of solenosteles and of petiole traces can be found in Gwynne-Vaughan (1901, 1903, p. 726), Bertrand and Cornaille (1902, p. 49) and Conard (1908). The general histology is strikingly similar in all these genera.

The stipe trace or meristele of the dennstaedtioid and cyatheoid ferns is often referred to in cross section as omega-shaped, horseshoe-shaped or U-shaped, but within this general plan a number of differential features occur. The open side of the U is oriented toward the adaxial side of the stipe, whereas the abaxial portion of the stipe strand is consistently convex and follows the contours of the stipe. Laterally the strand is constricted, in some cases nearly dividing the meristele into dorsal and ventral halves (*Fig. 1*). This can be termed the lateral groove. The adaxial portions of the trace diverge laterally and then converge along the adaxial margin. Here the ends of the U may turn inward as hooks facing toward the center of the rachis. This general, presumably primitive, plan is not totally present in any of the species examined; each exhibits various combinations of the following modifications:

FLUTING.—In many specimens the meristele becomes undulate or fluted with the flutings usually confined to the abaxial portion of the strand. The fluting may include all the tissues of the meristele from the endodermis to the xylem, as in *Dicksonia* (*Fig. 25*), *Metaxya* (*Fig. 23*), *Saccoloma* (*Fig. 20*), and some species of *Dennstaedtia* (*Fig. 6*). In other species of *Dennstaedtia* (*Figs. 2* and *3*) and in *Loxsomopsis* (*Fig. 18*) the xylem alone is fluted and the endodermis and pericycle are smoothly curved. In *Lophosoria* (*Fig. 21*), the outer endodermis is smoothly curved while the inner endodermis follows the fluted contours of the xylem.

DISSECTION.—The stipe meristele is unbroken in *Dennstaedtia* (*Figs. 1–6*), *Loxsomopsis* (*Fig. 18*), *Culcita* (*Fig. 19*), *Saccoloma* (*Fig. 20*), and *Metaxya* (*Fig. 23*). All other genera show tendencies toward dissection in at least some species. *Dicksonia* (*Fig. 25*) and *Lophosoria* (*Fig. 21*) have breaks in the lateral grooves which divide the strand into adaxial and abaxial portions. *Hypolepis* (*Figs. 8, 11*, and *13*) and *Paesia* (*Fig. 9*) have breaks at the lateral

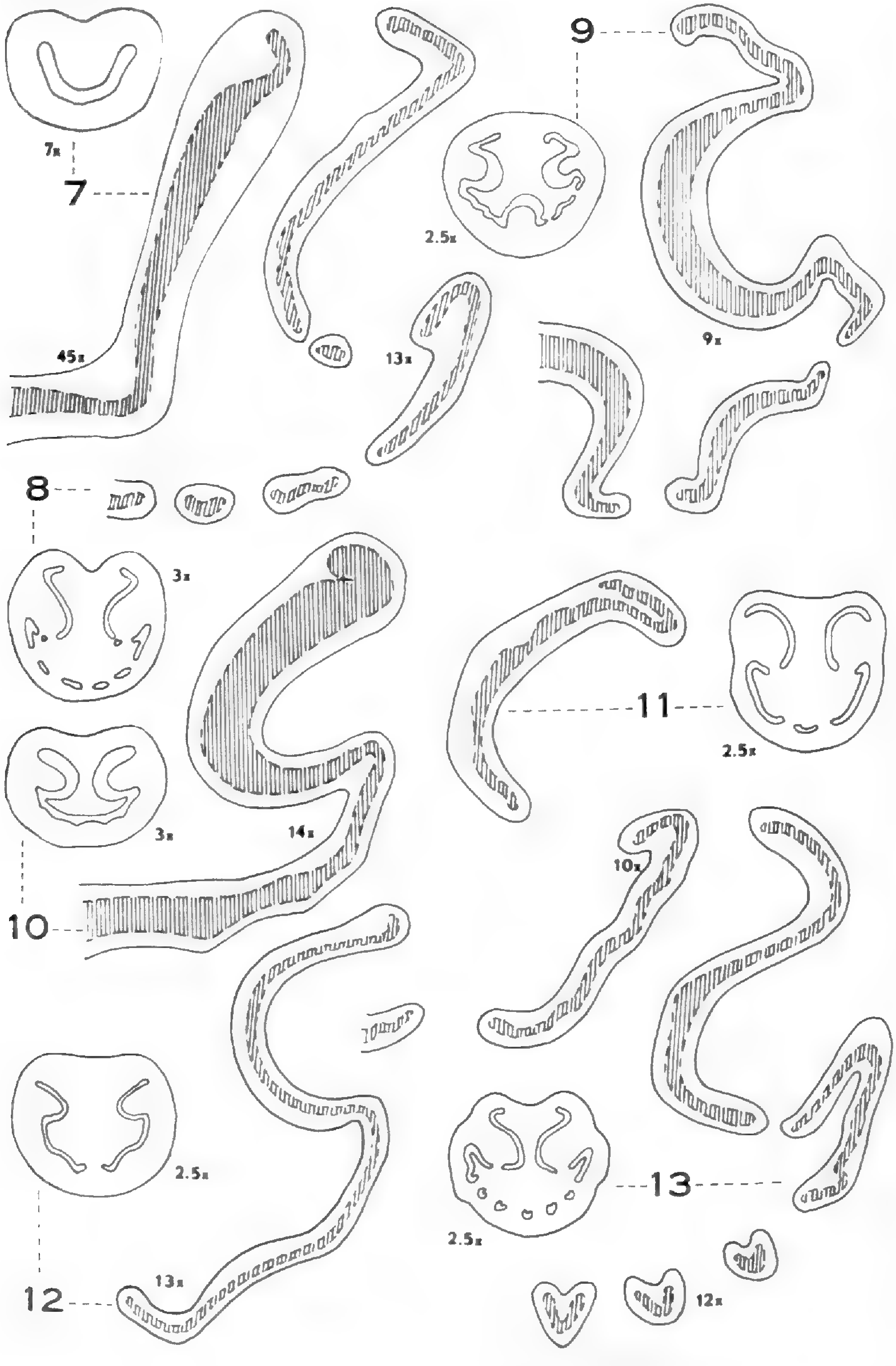


STIPE OUTLINES AND VASCULAR DETAIL

invagination and in the abaxial portion of the strand, resulting in several bundles with the same orientation as in an unbroken meristele. One species of *Pteris* (*Fig. 16*) examined also shows breaks in the abaxial portion. In *Pteridium* (*Fig. 24*) and in *Cyathea, Hemitelia* (*Fig. 26*), and *Alsophila,* the stipe vasculature consists almost exclusively of small bundles. Even in these genera, however, bundle orientation is similar to that described as the basic form. In some specimens of *Pteridium* the bundles appear as a nearly formless mass. Only in one specimen of *Pteridium* (*Fig. 24*) did the bundles show a clear orientation with easily distinguishable lateral grooves.

FUSION AND REDUCTION.—Tendencies toward stelar fusion and reduction in the stipe can only be interpreted when a large number of species and genera are studied. In this study nearly all of the various intermediate stages were found, and several trends are evident. Reduction in complexity of the stele and in the orientation of the adaxial portion of the strand from the ground plan type can be seen in *Dennstaedtia, Hypolepis* and *Pteris.* A comparison of the meristele outlines of *D. bipinnata* (*Fig. 2*) with *D. arborescens* (*Fig. 5*) and *D. cicutaria* (*Fig. 6*) gives the impression that meristeles are of two types: those with divergent and those with convergent adaxial trace ends. A closer examination of the figure details reveals that the course of the xylem is the same in each instance. In the outer edge of the adaxial portion of the meristele, the xylem tends to become folded tightly back on itself and the endodermis follows more economical contours (i. e., exposes less surface to the ground tissue). Intermediate stages can be seen in *D. spinosa* (*Fig. 1*) and in *D. dissecta* (*Fig. 3*), where the end of the xylem causes the endodermis to protrude slightly toward the center of the stipe. The direction of reduction tendencies is obscured in *D. obtusifolia* (*Fig. 4*), where the xylem completely encloses an island of phloem in the adaxial ends of the stele. The species of *Hypolepis* and *Pteris* examined show tendencies toward folding of the xylem which are similar to *Denn-*

FIG. 1. DENNSTAEDTIA SPINOSA. FIG. 2. D. BIPINNATA. FIG. 3. D. DISSECTA. FIG. 4. D. OBTUSIFOLIA. FIG. 5. D. ARBORESCENS. FIG. 6. D. CICUTARIA.



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staedtia. In the abaxial portion of the meristele, just below the lateral groove, a trend toward the folding of the xylem within the stele occurs in *Dennstaedtia* (*Figs. 3–5*) and in *Hypolepis* (*Figs. 8, 10*, and *11*).

LATERAL GROOVE DEPTH AND POSITION.—Constriction of the strand shows much variation. In *Cyathea*, *Alsophila*, and to some extent in *Hemitelia* (*Fig. 26*) the lateral groove is deep and narrow, dividing the stipe vasculature nearly equally in half between adaxial and abaxial portions. In *Hypolepis* (*Figs. 8, 10, 11*, and *13*) and *Dennstaedtia* (*Figs. 1–6*) the groove is oriented toward the adaxial side of the meristele and is variously shallow or deep. In *D. spinosa* (*Fig. 1*) the grooves are deep enough to allow the meristele to connect at the center of the stipe. The deeper grooves are found in larger stipes with generally more complex vasculature. Shallow grooves are due partly to general decrease in size and partly to previously mentioned folding and fusion tendencies. In *Pteris altissima* (*Fig. 15*) the grooves reach the extreme in orientation toward the adaxial side. In *Dicksonia* (*Fig. 25*) the grooves are located in the most abaxial position of any genus in this study.

CONCLUSIONS

It is difficult to conceive that independent origins are possible for genera with such similarity of ground plan in stipe anatomy. There is no reason to expect that features of stipe anatomy are sufficient in themselves to allow construction of a phylogeny (Bailey, 1951), but some trends of specialization are evident. In *Table III* the character states of stipe anatomy are presented as observed in this study. These trends are not based on solid evidence of unidirectional sequences, but on the fact that species with putatively reduced stipe features seem specialized in other characters. The conclusions of Bertrand and Cornaille (1902, pp. 40, 98, 211)

FIG. 7. HYPOLEPIS PULCHERRIMA. FIG. 8. H. SP. FIG. 9. PAESIA ANFRACTUOSA. FIG. 10. HYPOLEPIS SP. FIG. 11. H. BOGOTENSIS. FIG. 12. BLOTIELLA LINDENIANA. FIG. 13. HYPOLEPIS REPENS.

and Gwynne-Vaughan (1901, p. 95) regarding reduction and dissection were also used in establishing the directions of specialization.

None of the data have produced any straight line sequences of related genera. It is apparent, however, that similar evolutionary specializations have occurred. There seem to have been two major lines of specialization: the dennstaedtioid line and the cyatheoid line.

TABLE III. CHARACTER STATES IN STIPE VASCULATURE.

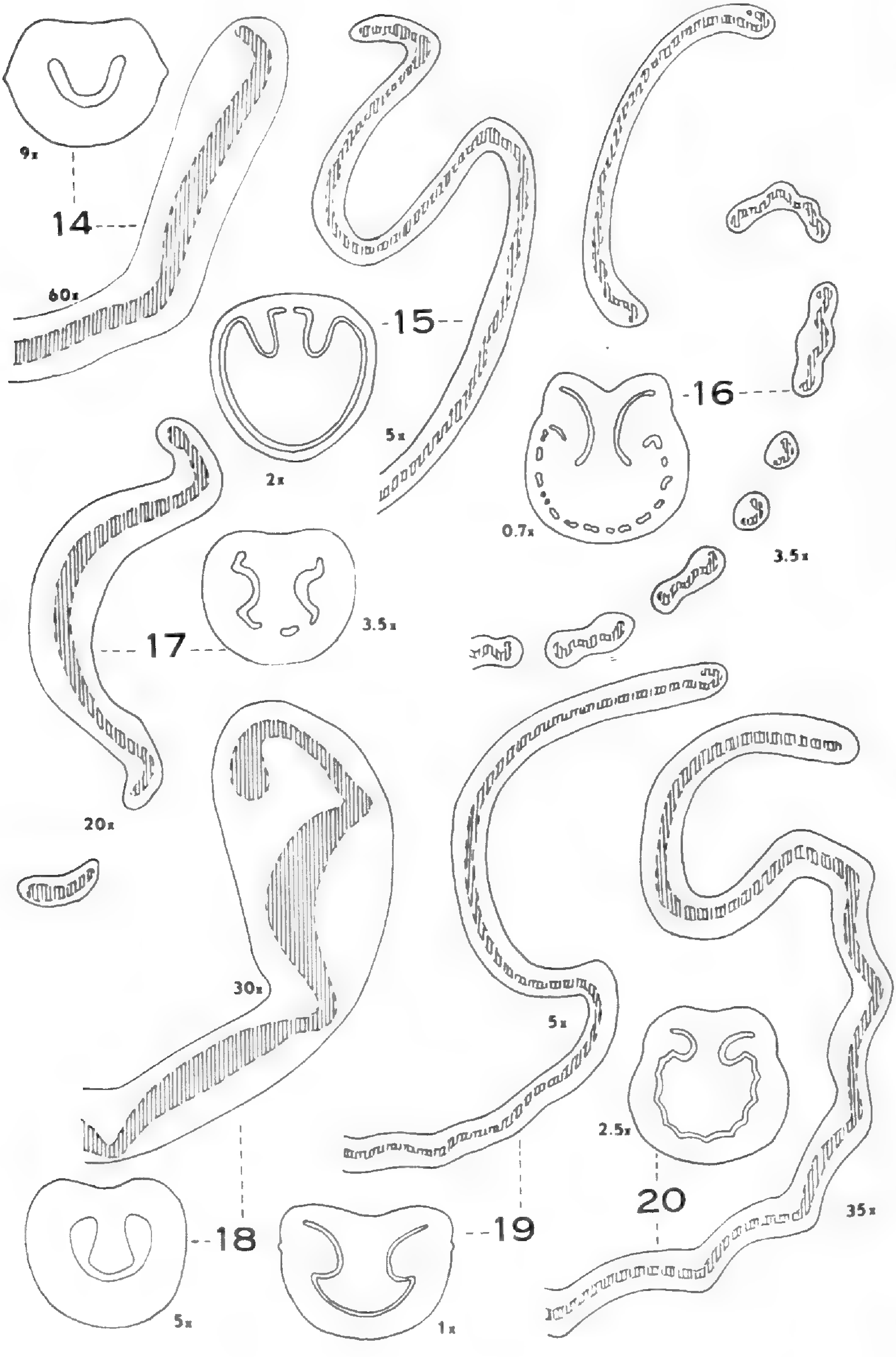
Primitive	*Advanced*
1. Stele contours smooth.	Contours fluted or undulate.
2. Stele unbroken.	Stele dissected.
3. Deep lateral grooves.	Shallow grooves or "U"-shaped trace.
4. Xylem symmetrically disposed between the outer and inner endodermis of the meristele.	Xylem fluted or folded within smooth contoured meristele margins.
5. Adaxial ends of the trace convergent and hooked.	Trace ends divergent or simple with erect ends.
6. Lateral groove centrally or adaxially oriented.	Lateral groove abaxially oriented.
7. Abaxial portion of the trace continuous.	Break in or absence of the abaxial portion of the trace, the vasculature divided into two equal lateral halves.

Table I lists specimens of dennstaedtioids with the character numbers from *Table III* which show the advanced state. In *Dennstaedtia* several trends are evident rather than a straight line of evolution. All the species of *Dennstaedtia* show at least one change from the generalized condition. The most consistent trend has been toward the elimination of the convergent ends of the trace on the adaxial side. This has occurred by the gradual folding of the inturned portion and hooks so that they lie flat against the sides of the stele, which tends to form a trace with U-shaped ends. In many species the remnants of the convergent ends are seen as small protrusions in the endodermis of the inward sides of the ends of the trace (*Figs. 1, 3, 4*). The ends of the trace usually reveal the folded xylem within the smooth contours of the stipe boundary. One temperate species, *D. punctilobula,* has a highly reduced, simple, V- or U-shaped meristele (Conard, 1908). Within the stele, however, the xylem has lateral grooves and convergent ends which are typical of the tropical species. The absence of lateral grooves in the meristele outline is a reduction tendency toward a simple vascular pattern.

The genus *Hypolepis,* which is probably a close relative of *Dennstaedtia,* usually shows distinctive stipe characters. Some *Hypolepis* specimens show tendencies toward dissection and toward reduction in length of the xylem on the abaxial portion of the trace. The small protrusions in the endodermis of *Dennstaedtia* mentioned above are not found in *Hypolepis,* indicating either a slightly different pattern of reduction or perhaps that intermediate conditions are not found in the species investigated (*Figs. 11* and *13*). *Hypolepis pulcherrima* (*Fig. 7*), with its simple, U-shaped meristele, has the most reduced stipe vasculature. It resembles the pattern found in *D. punctilobula* (Conard, 1908).

The two species of *Saccoloma* (*Fig. 20*) examined have nearly identical vasculature. The strand is nearly omega-shaped and the inturned hooks are gone, as are the folds in the xylem. The pattern does not show a close relationship with that of other genera described in this study.

In *Pteris* the three species examined also exhibit a divergent rather than a linear pattern of evolution. *Pteris altissima* (*Fig. 15*) shows no change in character states but is distinctive in having adaxially placed lateral grooves. *Pteris podophylla* (*Fig. 16*) has a dissected stele and the adaxial convergent ends have been lost. The xylem at the ends of the stele shows the vestige of a fusion as in *Dennstaedtia* and *Hypolepis. Pteris pungens* (*Fig. 14*) is the most reduced of the three, with a U-shaped strand with erect ends and the loss of lateral grooves. The evolutionary tendencies in *Pteris* show a clear relationship to those of *Dennstaedtia* and *Hypolepis.*



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Histiopteris incisa (*Fig. 17*) shows a distinct resemblance to *Hypolepis.* Its further specialization involves the loss of much of the abaxial portion of the trace which, in further reduction in *Blotiella* and *Lonchitis,* leaves two lateral traces instead of a U. *Blotiella lindeniana* (*Fig. 12*) is reminiscent of the *Pteris* type, but is also similar to *Paesia anfractuosa* (*Fig. 9*) with its abaxial deformation of the stele. It is also suggestive of *Hypolepis,* as pointed out by Tryon (1962). *Lonchitis hirsuta* (*Fig. 22*) possesses two traces oriented as in the thelypterid ferns; it is conceivable that the latter group is derived by this kind of reduction from the basic dennstaedtioid type. The vasculature of some species of *Thelypteris* and *Diplazium* resembles the dennstaedtioid type to a striking degree (Alan R. Smith, pers. comm.).

Pteridium aquilinum (*Fig. 24*) is a specialized type without direct relationship with other genera. The stipe stele is completely dissected, and tends toward apparent disorganization into a mass of bundles. The outline of the bundles includes an abaxial deformation which resembles the pattern of *Paesia* (*Fig. 9*) rather closely. On the basis of the features exhibited by these specimens, these genera might well be associated with the *Hypolepis-Histiopteris* line.

The cyatheoid ferns have been suggested by Holttum and Sen (1961) to belong to a separate line of evolution. Their changes in character states are listed in *Table II*. The cyatheoids have undergone as divergent an evolution as has *Dennstaedtia* and its immediate relatives. Although *Culcita* (*Fig. 19*) is associated with *Dicksonia* (*Fig. 25*) on the basis of other evidence, the divergent ends of the stipe stele with folded xylem (*Fig. 19*) is reminiscent of *Pteris, Dennstaedtia,* and *Hypolepis. Culcita dubia,* however, is reported to have inflexed ends on the stele (Holttum and Sen, 1961), and so the genus is probably compatible with *Dicksonia.* All other members of this assemblage of genera have well-developed vasculature with convergent adaxial ends with inward pointing hooks. *Lophosoria* (*Fig. 21*) and *Dicksonia* show close similarities,

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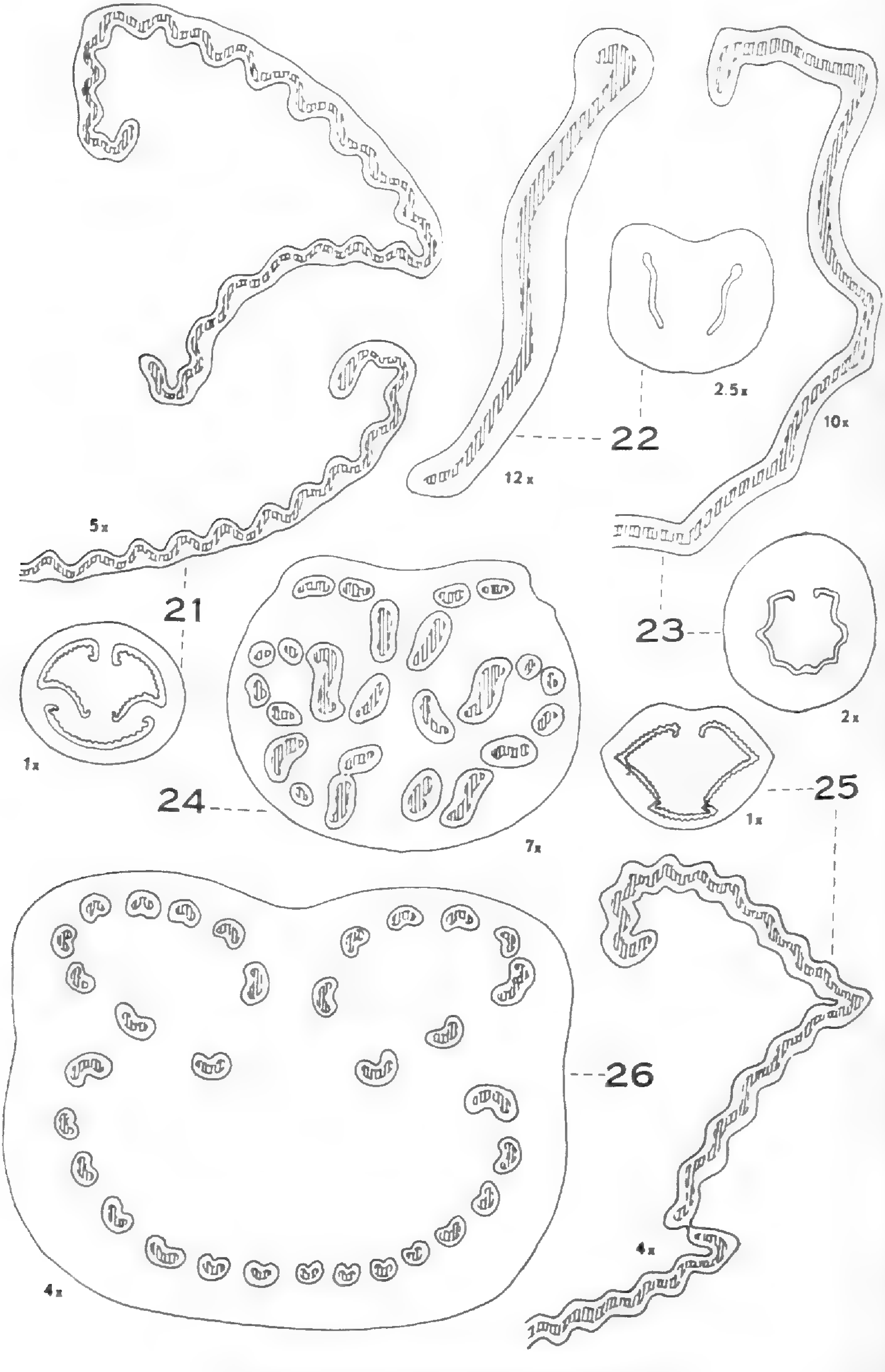
FIG. 14. PTERIS PUNGENS. FIG. 15. P. ALTISSIMA. FIG. 16. P. PODOPHYLLA. FIG. 17. HISTIOPTERIS INCISA. FIG. 18. LOXSOMOPSIS COSTARICENSIS. FIG. 19. CULCITA CONIIFOLIA. FIG. 20. SACCOLOMA ELEGANS.



Stipe Outlines and Vascular Detail

and *Metaxya* (*Fig. 23*) shows the same general plan. *Alsophila, Hemitelia* (*Fig. 26*), and *Cyathea* have stipes with the same basic configuration as *Lophosoria* except that dissection has taken place.

The conclusions of Holttum and Sen (1961) are supported in this investigation. The cyatheoid and dennstaedtioid lines of descent seem to be divergent lines from a common ancestor. In the cyatheoids the differences in dissection of the stipe trace support the suggestion by Maxon (1911) that the Cyatheaceae be divided into the Cyatheae and Dicksonieae. While it is probable that the cyatheoids terminate an evolutionary line, it is quite likely that the dennstaedtioids have given rise to other groups. The basic ground plan of the stipe in the dennstaedtioids is not incompatible with that found in many unrelated groups of ferns. Specimens I observed which show similarities in stipe vasculature include species of *Asplenium, Blechnum, Cheilanthes, Gleichenia, Jamesonia, Lindsaea, Odontosoria, Phlebodium, Polypodium, Thelypteris, Trichomanes,* and *Trismeria.* Although the stipes of each of these genera show diagnostic differences and, on the basis of stipe anatomy, no close relationship between them should be postulated, in each a high degree of simplification from the presumably primitive type is shown. Some have vestiges of lateral invaginations and convergent ends in the xylem even though the vasculature may consist of a simple arc of meristeles. As noted by Gwynne-Vaughan (1901, p. 95), this apparently universal design seems, with some exceptions, to be fundamentally typical for the Filicales. One could argue that parallel evolution could produce this ground plan in unrelated groups of ferns. The evidence from stipe anatomy for the species illustrated would not support any suggestion that these genera are polyphyletic. Different combinations of a limited number of modifications suggest radiation from a common ancestor. Available data promises that an extensive survey of the stipe anatomy in the Filicales would contribute greatly to our knowledge of phylogeny within that order.

FIG. 21. LOPHOSORIA QUADRIPINNATA. FIG. 22. LONCHITIS HIRSUTA. FIG. 23. METAXYA ROSTRATA. FIG. 24. PTERIDIUM AQUILINUM. FIG. 25. DICKSONIA GIGANTEA. FIG. 26. HEMITELIA CHORICARPA.

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Shorter Notes

A NOTE ON ASPIDOTIS.—The late E. B. Copeland was the first among modern pteridologists to take up *Aspidotis* (Nutt. ex Hook. & Bak.) Copel. as a genus. This genus is a segregate of *Cheilanthes,* although it was originally described as a section of *Hypolepis* and was considered a subgenus of that genus by Christensen. The New World species are distinguished by elongate, narrow, generally mucronate-rostrate and distantly toothed segments with thickened margins and a striate and shining upper surface and with broad, scarious, continuous or discontinuous indusia. *Aspidotis* contains *A. meifolia* (D. C. Eaton in Wats.) Pic.-Ser. from Baja California plus two species, *A. californica* and *A. densa*, and their hybrid, principally from the west coast of the United States. One eastern African species, *A. schimperi* (Kunze) Pic.-Ser., probably is not a true *Aspidotis*. The California hybrid is *A.* **carlotta-halliae** (Wagn. & Gilb.) Lellinger, comb. nov., based on *Cheilanthes carlotta-halliae* Wagn. & Gilb. (Amer. J. Bot. **44**: 738. 1957). One parent, *A. californica* (Hook.) Nutt. ex Copel., usually has been placed in *Cheilanthes*. The other parent is *A.* **densa** (Brack. in Wilkes) Lellinger, comb. nov., based on *Onychium densum* Brack. in Wilkes (U. S. Expl. Exped. **16**: 120, *t. 13, f. 2*. 1854). The generic position of the latter species has been considered problematical. It was placed in *Pellaea* by Hooker, who had an unusually broad concept of that genus. Diels placed it in *Cryptogramma*, as Brackenridge had done in *Onychium*, presumably because of its dimorphism, but this is slight compared to the true Cryptogrammas. Both *Cryptogramma* and *Cheilanthes* lack the striate, shining upper lamina surface of *Aspidotis*. Maxon placed both it (as *Cheilanthes siliquosa*) and *A. californica* in *Cheilanthes*, recognizing the close relationship of the two, which was later confirmed by the discovery of hybrids between them.—DAVID B. LELLINGER, *U. S. National Museum, Washington, D. C. 20560.*

Notes and News

CERATOPTERIS SPORES NEEDED.—I would like to receive collections of spores (or information concerning sources) from natural habitats of any species of the aquatic fern *Ceratopteris* for genetic and physiological studies. Ideally, ten or more individual plants in a natural population should be sampled. It is important that the spores from each individual plant be collected and maintained separately in individual envelopes. All collectors will be cited in publishing this research.—EDWARD J. KLEKOWSKI, JR., *Dept. of Botany, University of Mass., Amherst, Mass. 01002.*

Recent Fern Literature

A DICTIONARY OF THE FLOWERING PLANTS AND FERNS, by J. C. Willis, 7th ed., revised by H. K. Airy Shaw. University Press, Cambridge, England. 1967. xxii + 1214 + liii pp. **$18.50.**—Prof. R. E. Holttum has contributed an Introduction to Pteridophyta and has compiled the generic names of pteridophytes, both those he accepts and their synonyms, in this highly important and useful book. In general he has accepted the generic concepts of Copeland's "Genera Filicum," while admitting their probable artificiality in some cases. It is more difficult to understand his abandoning his own family classification (see J. Linn. Soc. London, Bot. **53:** 123–158. 1947 and Biol. Rev. **24:** 267–296. 1949) in favor of Pichi-Sermolli's, although, as he says in the Introduction, the latter is preferable to Copeland's uneven treatment of families. For in contrast to Holttum's classification, Pichi-Sermolli's (see Uppsala Univ. Aarsskr. **6**: **70–90**. 1958) suffers from a most regretable and, in my opinion, unjustified hierarchical inflation in some places.

Unfortunately, some of Holttum's most important work on Cyatheaceae and Gleicheniaceae is not taken into account in the "Dictionary." *Dicksonia* is in its own family and order, separate from the Cyatheaceae (cf. Phytomorphology **11:** 418–419. 1962), and *Diplopterygium* and *Sticherus* are both accepted (cf. Reinwardtia **4:** 257–261. 1957). Holttum has followed Copeland in recognizing several arbitrary "genera" in the Grammitidaceae and the many "microgenera" of the Hymenophyllaceae. But in the Introduction he acknowledged Morton's more conservative attitude, which he admits is defensible (cf. Contr. U. S. Nat. Herb. **38:** 35–89. 1967 and **38:** 153ff. 1968). Currently Holttum is studying the genera and groups of thelypteroid ferns, and so his recognition of *Cyclosorus, Goniopteris,* and *Meniscium,* which are closely allied to one another and to *Thelypteris sensu stricto,* may possibly be revised. In my opinion the greatest difficulties have occurred in the Adiantaceae, where fairly natural alliances, e.g., the Onychieae, containing *Actiniopteris, Anopteris, Cryptogramma, Llavea, Neurosoria,* and *Onychium,* and the Pellaeae, containing *Doryopteris, Ormopteris, Pellaea,* and *Saffordia,* have been sundered or markedly split. Among the Cheilantheae, *Adiantopsis* and *Notholaena* have been placed as synonyms of *Cheilanthes,* whereas *Aspidotis* and *Cheiloplecton,* which very possibly are not distinct from *Cheilanthes,* have been maintained. *Negripteris,* like *Sinopteris, Mildella,* and *Adiantopsis,* seems to be a specialized evolutionary endpoint in the Cheilantheae, but is given separate family status. The two gymnogrammoid tribes, Gymnopterideae and Eriosoreae, are largely combined in the Gymnogrammaceae, but *Syngrammatopsis,* which is a synonym of *Pterozonium* (Eriosoreae), has been placed in the Lomariopsidaceae. In contrast, the Schizaeaceae, a family closely related to the Adiantaceae, is maintained intact, despite the differences among the generic groups *Actinostachys* and *Schizaea, Lygodium,* and *Anemia* and *Mohria,* which could be separated more justifiably into three families than the Adiantaceae is into five.

The strong points of Holttum's compilation lie in his superior knowledge of Old World genera, which exceeds that of any other living pteridologist. But the New World genera, with which he is sometimes less intimately acquainted, have on occasion caused him trouble. Overall, the treatment is usable and certainly worthy of use. It also stands as a reminder to the revisors of the next edition of the "Dictionary"—and to pteridologists in general—that contributions of this breadth are best accomplished by the cooperation of several knowledgable workers.—D. B. L.

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American Fern Journal

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Alma Gracey Stokey (1877–1968)

Lenette Rogers Atkinson

Alma Gracey Stokey will be remembered for many things, but perhaps most especially for her enduring interest in the ferns and for her pioneering work on fern gametophytes. In recognition of this outstanding work, the American Fern Society, in 1953, made her its tenth Honorary Member and the first woman to receive this honor.

Alma Stokey was born June 17, 1877, in Canton, Ohio, the second of five children of Margaret Purvines and Charles Frederick Stokey. She grew up in rolling, fertile eastern Ohio, which may explain why she was so content to spend most of her life in comparable New England. After High School in Canton, she taught in a public school before entering Oberlin College, then interrupted her studies by teaching to finance her college course, and took her B.A. at Oberlin in 1904, where she remained as an assistant in botany (1904–6). Her interests at college seem to have been as varied as in her later life. She sang in a choral group, as she was to do in others later. Not an athlete, with no hope of making a team, she nevertheless played basketball because practice players were needed. She was interested in foreign languages, and became proficient in Latin, German and French. Her interest in botany began under Dr. Frederick Grover, one of Oberlin's outstanding teachers. She attained her Ph.D. at the University of Chicago under the tutelage of Dr. John M. Coulter and Dr. W. J. G. Land, and published her first botanical articles "The roots of *Lycopodium pithyoides*" in 1907 and "The anatomy of *Isoëtes*" in 1909. In 1908 she came to Mount Holyoke College as an instructor in botany, became an associate professor in 1911 and a full professor in 1916,

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ALMA G. STOKEY

and headed the department from which she retired in 1942. Oberlin College, her Alma Mater, bestowed upon her an honorary Doctor of Science in 1955.

Alma Stokey was trained in morphology and anatomy; her orderly and perceptive mind had early discovered the gaps in our knowledge of the fern gametophyte. Strongly urged and encouraged by Professor F. O. Bower of Glasgow University, Scotland, who is the author of a monumental comparative work called "The Ferns," she set herself and her graduate students to work filling some of those gaps.

The first comparative work was on the Cyatheaceae (1930). Here the presence of multicellular hairs on thalli of *Cyathea* and its close relatives and their absence in *Dicksonia* and its relatives encouraged her to think that the little known gametophytes might indeed contribute valuable characters to the study of fern relationships.

As the study of *Cyathea* was nearing its close (1929), there came a request for help in finding a competent teacher to organize the botany department at the Women's Christian College, Madras, sister college of Mount Holyoke. Alma Stokey was interested in this proposition and was influenced also, without a doubt, by the vision of hordes of ferns awaiting her in the tropics. She obtained two years' leave of absence and filled the position herself. Five years later she returned to Madras for another year. She wrote from Madras in 1936, "I have just filled out a blank for the Registrar of the University of Madras concerning age, degrees, etc. 'Special subject and qualifications for teaching if any' is too much for me, and I am in a proper state of humility, so I pass it over and leave it to them to find out."

Alma Stokey's sojourn in India and her three journeys around the world had a profound influence upon her. Her enthusiasm for her teaching in Madras, which extended her botanical education considerably, and her delight in the collecting trips she made into the mountains of India and Kashmir, in Ceylon, Java, and Formosa shine through her serial reports to family and friends (India Inklings and Java Jottings) and through her letters to me. In

1929, soon after her arrival in Madras, she wrote:

"I walked out to pick a few plants to use as illustrations and discovered afterwards that countless [students] had seen me do it and even knew what I had picked, which is more than I did myself. . . . New Families ! ! ! ! ! ! I walk around the compound reviewing what I have learned and getting new things whenever I have a chance. I am learning countless representatives of the Euphorbiaceae. Every third plant [seems to belong] to the Euphorbiaceae, the Malvaceae or the Leguminosae. So far no ferns. Madras is poor in ferns . . . but I am going to Ceylon."

In October, 1929, returning from Michaelmas vacation she said,

"How I did wish in Ceylon . . . for someone who was interested in ferns . . . When I went to Hakgala [5600 ft. alt.] I saw tree ferns rampant all along the jungle and bordering streams—magnificent specimens of *Hemitelia Walkerae*, *Alsophila crinita*, and *A. glabra*. They are really impressive. I saw *Angiopteris evecta* growing wild -found it myself. I had a good vacation but it seems good to be back in Madras raising fern prothalli."

In May, 1931, on her way back to Mount Holyoke, Miss Stokey worked for a month at the Treub Laboratory, Buitenzorg, Java. She wrote,

"I am now in the Paradise of Botanists . . . I have been here a little over two days and began work this morning. Seven is the correct hour but at seven I barely had one eye open and it was eight before I reached the laboratory. The correct thing is to work until two and then go home and let it rain. I see why rijstaafel was invented. From seven to two is a long period without sustenance and one needs the three square meals which are provided in rijstaafel. This morning I collected *Kaulfussia*, now labelled *Christensenia*. . . . one of the thrills of my Botanical Life, *Macroglossum Smithii*, *Angiopteris subfurfuracea*, *A. Miqueliana*, *Lygodium*, and *Cyathea*. I hope to go to Tjibodas [4500 ft. alt.] soon and get some of Professor Bower's *Plagiogyria*. By the way, he wrote me a very nice letter which I shall save and frame along with the testimonial which the students gave me in Madras. Anybody who thinks I am a fool will be referred to them—I doubtless shall need to refer to them myself occasionally . . . I am also consumed with curiosity to see if *Plagiogyria* germinates like a Polypod or . . . like a primitive type. I hope it is fruiting now. The ferns are apt to fruit in the dry season and it is just beginning. Polypods are much easier to work with as they fruit more steadily and do not go so much by seasons and they have a mixed sorus so that the fruiting period is longer. It seems good to be in a laboratory again after having wandered around for over a month."

Again from Buitenzorg in July, 1937:

"My absorbing work is the Hymenophyllaceae. I never intended to do much with them. I started one in 1936 just to have a specimen to show my class in ferns. I found it so much more impressive than anything published that I decided to collect more. . . . They are quick at first and then slow; that just suits me. I can give my attention to them here and get the early stages and then dally along four or five years for the mature ones. I am the right age for that [she was 60]—old enough to know that five years will pass and young enough to hope to outlive them . . . I made three trips to the forest around Tjibodas. At first I wanted to pick Filmy Ferns every time I saw them but that had to be given up, as not even a coolie who is used to carrying a load up to 60 to 80 pounds could live up to that. . . . I went up to the mountain laboratory [at Tjibodas] for six days and then had a trip from there to Labak Saät, a walk of ten miles with an ascent to 8000 feet. It is a paradise for ferns; that was where I got *Plagiogyria* and some of my filmy ferns. We saw plenty of *Dipteris*, but it was easier to collect in the garden at Tjibodas as I do not scale vertical faces of cliffs. . . . At present I have about 60 cultures running. . . . I shall try to reduce to 30 for travelling. There will not be room on my bed on the boat for more. . . . nor will my basket hold more. . . . The burning question now is: Can I keep my saman [luggage] at seven pieces or will it grow to eight? I cannot throw away garments as rapidly as I acquire ferns. I am thinking of travelling by airplane as that is the only way to be sure not to collect."

While at Buitenzorg, an ascent of Mount Salak was also arranged

"to see *Christensenia* in its native heath . . . a very primitive and peculiar fern. It is pictured in all the books dealing with fern types and it is always the same picture which does not give a very good idea of it. It grows 18–24 inches high and has a leaf like a buckeye, with very peculiar fructifications on the under side. . . . I was told to wear trousers and spiked shoes for the trip . . . We walked nearly an hour up the gentle slopes covered by tea plantations, then plunged into a forest along a path, man-sized in width but not in height. I was so charmed with the beautiful Selaginellas, especially a large one of iridescent blue that I had great difficulty in keeping to my feet. . . . began a steep ascent. . . . used my hands freely until the coolie in front of me encountered a scorpion and was stung on the foot (apparently not badly), then into a ravine . . . the bank was very steep and very wet and very much covered with lianas which have a nasty way of catching the foot and pulling the hair . . . . Only three Christensenias but the richest place I have ever seen . . . the riotous luxuriance of tropical rain forest of which I studied in my youth . . . It

> was a most enjoyable excursion; I contrasted it with the expedition in Hakgala, Ceylon, where my attendants were more concerned with keeping me intact than in finding ferns . . . no one seemed unduly concerned [on Mount Salak] about my skin or bones and did not help me unneecessarily. I would rather be a Botanist than a Lady."

Any area promising ferns intrigued her. She also made two trips to Jamaica and spent a winter in Hawaii.

By 1951, after publishing on the development of the thallus in the Cyatheaceae, Hymenophyllaceae, Marattiaceae, *Dipteris*, *Actiniopteris*, and Gleicheniaceae, it had become evident that although sensitive to environmental change and made unstable by it, the tiny gametophytic plants showed differences and similarities which could be useful. In 1960, on the occasion of the first publication of Phytomorphology, the official organ of the International Society of Plant Morphologists, Miss Stokey published her well-documented thesis "The contribution of the gametophyte to classification of the homosporous ferns." The title could as well have read "The development and characteristics of the thallus as an aid to understanding fern relationships and evolution." It had become apparent that certain gametophytic characters are relatively stable and often constant for a genus: Germination as a mass or as a filament; development of the plate from the terminal cell or cells of the filament or from subterminal cells if the filament ends in a hair; symmetrical or asymmetrical thallus when the meristem is apical or lateral; color of rhizoids; kinds of hairs; type of antheridium, that is, whether the wall consists of three or four cells or of several cells; type of archegonial neck, that is, cylindrical or bulbous, long or short, curving away from or toward the notch. Her writing was concise, her standards high both for herself and for her students. At Mount Holyoke College, at Woods Hole, in Java and Formosa, and at the Women's Christian College, Madras, India, Alma Stokey pursued her studies. After her retirement from teaching in 1942, she gave full time to research, growing thalli of some 300 ferns from spores collected by herself or others, and publishing some 30 articles.[1]

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[1] The majority appear in the Botanical Gazette, Bulletin of the Torrey Botanical Club, Phytomorphology, or The American Fern Journal. Much of her work is still being edited.

In her teaching Miss Stokey, admiring Agassiz, was a strong believer in the direct approach, and weekly field trips in spring and fall were an integral part of her courses. Nor did she lack that professorial attribute, absent-mindedness. So intense was her desire to cover as much ground as possible that she often left her Gray's Manual behind at some spot where the class had stopped to run down a flower in the key.

Besides her teaching, departmental administration, and faculty committees, Miss Stokey found time to help organize the Mount Holyoke War Garden, 1917–1919, one of the first of its kind, to serve on the College Entrance Examination Board, to contribute abstracts to Botanical and Biological Abstracts, and to serve 20 years on the Associate Board of the Women's Christian College, Madras—11 years as Chairman of the Personnel Committee, and seven as Corresponding Secretary.

Miss Stokey's family meant much to her. She solved the problem of vacationing with them and continuing year-round research by building a cottage, appropriately named Fernbank, near the Marine Biological Laboratory at Woods Hole. Her captivation with the area and its colony was rapid and complete. In 1914 her first proposed visit of one week stretched into six. The next year she bought a building lot there sight unseen, so sure was she that nothing near the laboratory could be undesirable. She was a member of the Corporation from 1917 until her death.

Alma Stokey was blond, blue-eyed, stocky, and endowed with such excellent health that she did not have to give it conscious thought. Although she was short, she developed an unproportionately long stride which often left her friends and students panting far behind. When asked about her hobbies, she gave walking as the first. This she indulged in in unusual ways: Walking along the English Downs, or in the Swiss Alps, or up Mount Washington in New Hampshire, or climbing Adams Peak in Ceylon with the faithful to see the sun rise. At 53 when she might easily have preferred her own fireside, she went on a camping trip in Kashmir:

> "We could get only six [pack] ponies so we abandoned six chairs. Really, I wish you could see the style in which we camp. This is late in the season in

Kashmir and we had to use the winter route, in snow-filled valleys, to go to Zoja La Pass—five miles, up 2000 feet [from 9300 to 11300 feet alt.]. But that isn't my best effort! . . . We could have gone three or four miles more if it had been meadow instead of snow. It is not a spectacular pass like the Khyber, . . . but we found it interesting. We met caravans of ponies carrying numbdahs [rugs] made in Ladakh and brought to Srinagar to be embroidered, lamas, coolies, mail runners, yaks, and nothing else but snow and mountains."

There were other interests. She enjoyed music. She liked to sing and her musical appreciation was, I think, critical and penetrating. Her friends will remember the dozens of picnics she organized and the Indian dinners she cooked. At one time she found it interesting to join an etching class in a nearby city.

Alma Stokey left the working world a little time ago when deafness and physical debility set her somewhat apart. She possessed the desire and ability to study and learn, which continued and increased throughout most of her life. She disliked and avoided altercation, but when necessary did not mince words. Her adaptability in new places, her humor, her enthusiasm, her critical judgement and integrity, the disarming humility which concealed so well her talents—all these qualities made Alma Stokey an outstanding and unusual woman.

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Polypodium vulgare on Long Island

F. R. FOSBERG

On Sugar Loaf Hill, on the southern coast of eastern Long Island, Suffolk County, New York, is a small colony of *Polypodium vulgare* growing on sand, a most unusual habitat for this species in eastern North America. I was taken to this colony by Mr. George Peter, an amateur naturalist and former Long Island resident, and by Mrs. Grosvenor Atterbury, owner of Sugar Loaf Hill, which is one of the Shinnecock Hills west of Southampton.

The *Polypodium* (*Fosberg 50490,* US) is found on the eastern slope of the hill, at about 65 m elevation, in a patch of hardwood forest growing on a sandy morainal soil with no rock outcrops or even boulders in the immediate vicinity, although there are glacial boulders not far away. It is in a rather dense but not very tall hardwood forest of *Prunus serotina, Robinia pseudo-acacia,* and several oaks, with a thick undergrowth of *Smilax, Viburnum,* and other shrubs.

The unusual habitat suggested that it would be worth while to check very carefully to be sure that the plant was not the European *P. vulgare* var. *vulgare* rather than the American var. *virginianum.* I have never seen the latter on any substratum but rock, but I saw var. *vulgare* growing on sand in Europe some years ago. An examination showed no trace of the peculiar glandular paraphyses in the sori that are the characteristic feature of var. *virginianum.* These two varieties seem indistinguishable in any other way. Therefore, the plant of Sugar Loaf Hill seems to be *Polypodium vulgare* var. *vulgare.*

Is this fern indigenous on Long Island? To the best of my knowledge var. *vulgare* is not known to be indigenous elsewhere in the eastern United States, although some California plants seem identical with the European ones.

In the abundant eastern North American material in the U.S. National Herbarium, filed under *P. virginianum* L., there is not a single specimen from a Coastal Plain locality. Of those specimens bearing habitat data, all grew on rocks, none on sand. Plants from doubtful localities were examined, but all had the characteristic glandular paraphyses of var. *virginianum*.

According to Mrs. Atterbury, Sugar Loaf Hill was rather bare 90 years ago, and this is supported by a photograph in her possession which shows only low vegetation. Whether the slope with the *Polypodium* was bare or wooded is not so clear. There is a considerable wooded area now, and there are some introduced trees in the vicinity, including European oaks and beech. These were brought in by the Atterbury family, and the *Polypodium* might have come with them. On the other hand, there are in the eastern United States a number of species with an amphi-Atlantic distribution, and this could be one of them. It is very difficult to be sure which of these are indigenous and which crossed the Atlantic with the aid of man; it may never be certain in the case of *Polypodium vulgare* var. *vulgare*. The best approach would seem to be to search for other Coastal Plain and morainal stations in order to see which variety is present.

Mrs. Atterbury intends to preserve a small area surrounding the *Polypodium* colony in its natural condition, so that it will be possible to study its behavior in the future and to study more carefully the vegetation in which it occurs. It is hoped that she will provide for its permanent legal preserved status for all time.

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Notes on Ryukyu Ferns[1]

DAVID B. LELLINGER

Dr. Egbert H. Walker is currently preparing a new vascular plant flora of Okinawa and the southern Ryukyu Islands which lie between Okinawa and Taiwan. These islands separate the Pacific Ocean from the East China Sea and lie in a northeast–southwest line to the southwest of the Japanese island of Kyushu. The following notes mostly concern those fern species and varieties in the Ryukyu flora for which a change of name is necessary.

COLYSIS × SHINTENENSIS (Hayata) H. Ito, J. Jap. Bot. **11:** 90. 1935, *pro. sp.*

Polypodium ellipticum var. *simplicifrons* Christ, Bull. Herb. Boiss. II, **2:** 832. 1902. TYPE: Kyushu, Japan, base of Mount Nagasaki, *Faurie 4987* (P not seen).

Polypodium wrightii var. *lobatum* Rosenst. Hedwigia **56:** 347. 1916. (as "*lobata*"). TYPE: Shinton [*sic*], Taiwan, *Faurie 215* (S not seen; isotype TI not seen).

Polypodium shintenense Hayata, Icon. Pl. Formosa **8:** 154, *f. 85, 86.* 1919. Based on *P. wrightii* var. *lobatum.*

Colysis elliptica var. *pothifolia* f. *simplex* Ching, Bull. Fan Mem. Inst. Biol., Bot. **4:** 335. 1933. SYNTYPES: Kwantung Prov., China, Tung Ping-hsien, *K. K. Tsoong 1483*; Ko-chow, *Y. Tsiang 2285, 7638.* Hong Kong, China, *Tutcher 10119, Matthew 70* in 1907. Taiwan: *Oldham.*

Colysis simplicifrons (Christ) Tagawa, J. Jap. Bot. **25:** 114. 1950.

Colysis wrightii var. *lacerata* Nakai, Bull. Nat. Sci. Mus. Tokyo, No. **27:** 24. 1950. TYPE: Kyushu, Japan, Prov. Hyuga, Kitago, April 7, 1948, *Nakai* (TNS not seen).

This species demonstrates hybrid irregularity in blade outline (*Figs. 2* and *3*), and may be added to the other examples of Filicineae discussed by Wagner (1962). Its parents probably are the other two species of *Colysis* known from the area, *C. elliptica* (Thunb.) Ching (*Fig. 1*) and *C. wrightii* (Hook.) Ching (Fig. *4*). The hybrids have fewer sporangia and more paraphyses than the parent species. Few of the sporangia develop fully, and those that do develop fail to produce spores and do not dehisce in a normal manner. The fronds of the hybrid specimens are usually

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[1] Partial cost of publication has been borne by the Smithsonian Institution.

intermediate between the parents, but a few of them resemble one or the other of the parent species fairly closely. In fact, specimen number 7494 from Tetsuo Amano's herbarium has on a single rhizome one frond resembling one parent and another resembling the other. The hybrid is known from Saishu Island (Quelpart), Japan, and the Ryukyu Islands.

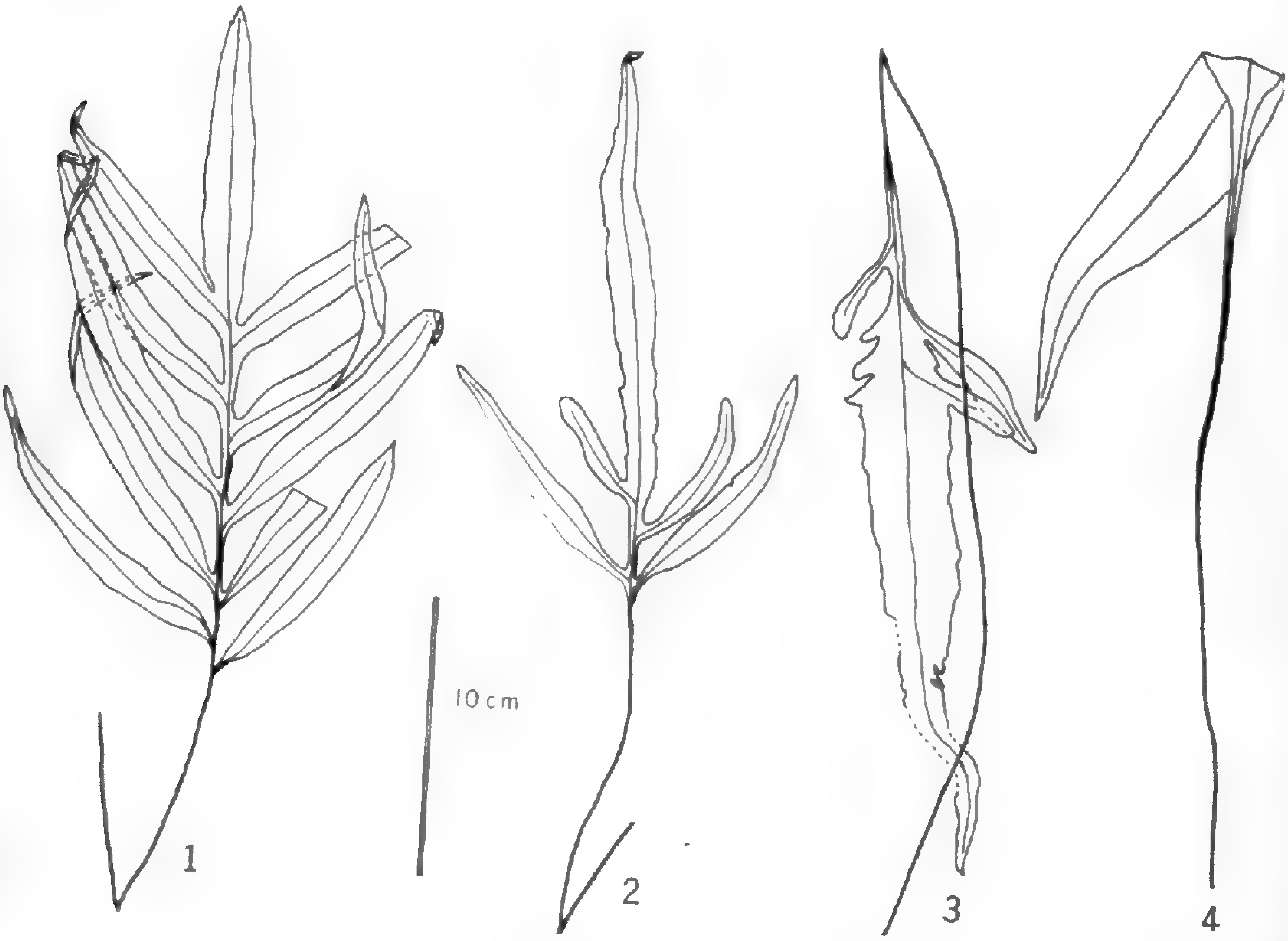

FIG. 1. FROND OUTLINE OF COLYSIS ELLIPTICA (CONOVER 946, US). FIGS. 2, 3. SAME, C. × SHINTENENSIS (TAWADA 1602, HERB. AMANO; OYAMA 796, KYO). FIG. 4. SAME, C. WRIGHTII (SONOHARA 128, US).

TECTARIA **dissecta** (Forst.) Lellinger, comb. nov.

Polypodium dissectum Forst. Fl. Ins. Austr. Prodr. 81. 1786, *non* Swartz, 1788.

Dryopteris dissecta (Forst.) Kuntze, Rev. Gen. Pl. **2**: 812. 1891. See p. 262 of Christensen's "Index Filicum" for additional synonyms.

Ctenitopsis dissecta (Forst.) Ching, Bull. Fan Mem. Inst. Biol., Bot. **8**: 321. 1938.

Ctenitis dissecta (Forst.) H. Ito in Nakai & Honda, Nov. Fl. Jap. **4**: 91. 1939.

Holttum (1954, p. 305) reduces *Ctenitopsis* Ching to *Tectaria*, citing the artificial distinction of the former, which is based on the character of free venation alone, without additional supporting characters having been adduced.

TECTARIA **kusukusensis** (Hayata) Lellinger, comb. nov.

Dryopteris kusukusensis Hayata, Icon. Pl. Formosa **4:** 157. 1914. TYPE: Kusukusu [Island], July 1912, *Hayata & Sasaki* (TI not seen).

Ctenitis kusukusensis (Hayata) H. Ito in Nakai & Honda, Nov. Fl. Jap. **4:** 93. 1939.

Ctenitopsis kusukusensis (Hayata) C. Chr. ex Tard.-Bl. & C. Chr., Notul. Syst., Paris **7:** 87. 1938.

Dryopteris membranoides Hayata may be referable here, but not having seen the type specimen, I hesitate to place it in synonymy on the basis of the description and illustration alone.

THELYPTERIS subg. LEPTOGRAMMA (J. Smith) Reed, Phytologia **17:** 254. 1968.

Leptogramma J. Smith, Hook. J. Bot. **4:** 51. 1841. LECTOTYPE: *L. totta* J. Smith (= *Thelypteris pozoi* (Lag.) Morton), chosen by C. Christensen (Ind. Fil. XXI. 1906).

Stegnogramma Blume, Enum. Pl. Jav. 172. 1828. TYPE: *S. aspidioides* Blume (= *Dryopteris stegnogramma* (Blume) C. Chr.).

Dryopteris subg. *Leptogramma* (J. Smith) C. Chr., Ind. Fil. 250. 1905.

Dryopteris subg. *Stegnogramma* (Blume) C. Chr., Ind. Fil. 250. 1905.

Thelypteris sect. *Leptogramma* (J. Smith) Morton, Amer. Fern J. **53:** 153. 1963.

Thelypteris subg. *Stegnogramma* (J. Smith) Reed, Phytologia **17:** 254. 1968.

That neither *Leptogramma* nor *Stegnogramma* deserves generic status has been discussed by Morton (1966). My choice of subgeneric name is intended to preserve the use of the name *Thelypteris* subg. *Leptogramma* (J. Smith) Reed for those who unite *Leptogramma* and *Stegnogramma*.

TRICHOMANES RADICANS var. **naseanum** (Christ) Lellinger, comb. nov.

Trichomanes naseanum Christ, Bull. Soc. Bot. France **52** [IV, **5**]: 11. 1905. TYPE: Su-tchuen [Sze-ch'uan], China, Mount Omei [Omi], 3000 m alt., *Faber 102* (P not seen).

Vandenboschia radicans var. *naseana* (Christ) H. Ito, J. Jap. Bot. **24:** 124. 1949.

TRICHOMANES RADICANS var. **orientalis** (C. Chr.) Lellinger, comb. nov.

Trichomanes orientalis C. Chr., Ind. Fil. 646. 1906.

Trichomanes japonicum Franch. & Sav. Enum. Pl. Jap. 2: 207, 618. 1879, *non* Thunb. 1784, *nec* Poir. in Lam. 1808. TYPE: Japan?, *Savatier 1614bis* (P not seen).

Vandenboschia radicans var. *orientalis* (C. Chr.) H. Ito., J. Jap. Bot. **24:** 125. 1949.

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TRICHOMANES MAKINOI var. **tosae** (Matsumura) Lellinger, comb. nov.

Trichomanes tosae Christ ex Matsumura, Bot. Mag. Tokyo **24:** 240. 1910. TYPE: Tosa, Shikoku Island, Japan, without locality or collector (TI not seen).

Crepidomanes makinoi var. *tosae* (Matsumura) K. Iwats. Acta Phytotax. Geobot. **17:** 72. 1958.

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The Fern Collections in Some European Herbaria

C. V. MORTON

In 1954 I was granted a Guggenheim Fellowship to study and photograph fern types and other interesting specimens in various European herbaria. During that year I visited the Botanisch Museum, Utrecht, the Rijksherbarium, Leiden, the Muséum National d'Histoire Naturelle, Paris, the Conservatoire Botanique, Geneva, the Jardin Botanique de l'Etat, Brussels, the Staatsinstitut für Allgemeine Botanik, Hamburg, the Botanical Museum, Copenhagen, the Naturhistoriska Riksmuseet, Stockholm, the Botanical Museum, Oslo, the British Museum (Natural History), London, and the Royal Botanic Gardens, Kew. Since 1954 I have visited Europe many times, studying in some of these same herbaria and also visiting the Istituto Botanico, Florence, the Naturhistorisches Museum, Vienna, the Botanischer Garten, Berlin-Dahlem, the Institut für Systematische Botanik, Zürich, and the Royal Botanical Garden, Edinburgh.

Not much, if anything, has ever been published that is readily available on the fern collections of these herbaria or on their history, which may be of more general interest. This paper records my own observations on the collections and some notes on the history taken from various publications.

BRITISH MUSEUM (NATURAL HISTORY)

In 1954 I spent about six weeks examining the fern collections in the British Museum (Natural History) in London. I found these rich collections in good order due to A. H. G. Alston's efforts.

The British Museum dates from 1753, when the Government purchased the collections of Sir Hans Sloane, which contained a large number of miscellaneous objects, including 265 (one account says 333) large folio volumes of herbarium specimens. The Sloane Herbarium, kept as a separate unit, naturally, is perhaps the second most valuable collection of the Department of Botany. An interesting book on it has been published by Mr. James Dandy. The Herbarium contains Sloane'e own collections from Jamaica (the basis of the descriptions and drawings in his "Natural History of Jamaica"), the collections of Plukenet and Petiver (the basis of their various books), and the old herbarium of Hermann Boerhaave. English plants from the early English botanists like Ray, Sherard, Miller, and American plants from Banister, Bartram, Catesby, Houstoun, and others are also included.

Sir Joseph Banks, who had accompanied Captain Cook on his first voyage,[1] amassed a large collection of herbarium specimens, of his own collecting and others. Banks employed as Keeper

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[1] There is an exceptionally interesting account of this voyage and of Banks in the new book "The Fatal Impact" [the name referring to the impact of Europeans on the natives of the South Sea Islands], by Alan Moorehead.

Robert Brown, perhaps the most celebrated English botanist of his day. The Banks Herbarium came to the British Museum in 1827, and Brown was appointed "Keeper of Sir Joseph Banks Botanical Collection." A "Botanical Branch" was formally established in 1835 by the union of the Banks Herbarium, the Sloane Herbarium, and various other assembled collections, again with Brown as Keeper. In 1856, two years before Brown's death, the name was changed to the Department of Botany.

Among the treasures of the Banks Herbarium, the single most valuable in the British Museum, were the plants of Clifford (the specimens used by Linnaeus for his "Hortus Cliffortianus," 1737, and so the types of many Linnaean species), the collections of Paul Hermann (1640–1695) from Ceylon (used by Linnaeus for his "Flora Zeylanica," 1747), the Virginian collections of John Clayton (1686?–1773) (the basis of Gronovius' "Flora Virginica"), the herbarium of Philip Miller (the basis of the many species described in his "Gardener's Dictionary"), cultivated plants of Kew (the basis of the new species of Solander and Dryander published in Aiton's "Hortus Kewensis"), an original herbarium of Baron Nicolaus Jacquin (1727–1817) (the basis of his four-volume work on the Schönbrunn Garden), the original collections of J. R. and G. Forster from the South Seas, William Roxburgh collections from India and elsewhere, the collection of J. G. Koenig from Ceylon, the Indian collections of Francis Buchanan-Hamilton (the basis of David Don's "Prodromus Florae Nepalensis," 1825), collections of John Bartram from Georgia and the Carolinas (1765–1766), of Peter Kalm (1717–1779) from Canada, of Archibald Menzies (1754–1842) from the western United States, and others too numerous to mention. Except for the specimens mounted in books, the Banks Herbarium is mounted and distributed into the general herbarium. The collections are not marked to indicate their origin.

Robert Brown's personal herbarium was bequeathed to J. J. Bennett, who in turn bequeathed it to the British Museum. It contained especially Brown's own specimens collected on the Flinders Expedition to Australia and Tasmania in 1802–1805, the types of the species described in Brown's "Prodromus Florae Novae Hollandiae" (1810).

Among the other most important collections are the James Sowerby Herbarium of English plants, 5750 plants of the United States from Thomas Nuttall (the types of many of Nuttall's species, often represented by very scrappy material), the South Carolina plants forming the basis of Walter's "Flora Caroliniana" (1788), Roemer's Herbarium (the basis of the new species described in the Roemer & Schultes' edition of Linnaeus' "Systema Vegetabilium"), 11920 Hepaticae from Stephani (including types or isotypes of many new species), plants from Aublet described in the "Plantes de la Guiane" (1775), W. Griffith's East Indian Herbarium, the original herbarium of Guiana plants from Edward Rudge, and the original herbarium of Peter Pallas (1741–1811) (including his own types and those of Gmelin's "Flora Sibirica").

Some other collections are more important for ferns, especially the herbarium of Carl Christensen (acquired shortly before World War II). Among these herbaria are the original herbarium (10,000 ± specimens) of John Smith (1798–1888), Berthold Seemann (1825–1871) (collections described in the "Voyage of the Herald" and in the "Flora Vitiensis"), C. B. Clarke (11,155 ferns from India, the basis of Clarke's publications on Indian ferns), C. W. Hope (Assam), Richard Henry Beddome (more than 10,000 Indian ferns), the original fern herbarium of Edward Newman, and many collections of Milne, Harvey, MacGillivray, and others from the South Sea Islands, of great interest to me since I am working on an account of the ferns of Fiji.

Subsequent Keepers and Assistants in the British Museum up until the end of the Nineteenth Century included many famous names, such as J. J. Bennett, W. Carruthers, G. R. M. Murray, H. Trimen, J. Britten, H. N. Ridley, W. Fawcett, A. Gepp, E. G. Baker, and A. B. Rendle.

I have always been most cordially received at the British Museum, in 1954 by the then Keeper, Sir George Taylor (now Director of the Royal Botanic Gardens, Kew), and in subsequent years by Mr. James Dandy and Mr. Robert Ross. I am especially grateful for the willing help accorded me by Mr. J. A. Crabbe. I photographed 1,715 ferns in 1954 and more in later years.

MUSÉUM NATIONAL D'HISTOIRE NATURELLE, PARIS

I first visited Paris at the time of the Eighth International Botanical Congress in 1954, at which time I spent about two months studying ferns in the Museum. Since then I have visited Paris several times, and have always been most cordially received by the Director, Professor H. Humbert and later Prof. A. Aubreville, and by the Assistant Director, Madame Tardieu-Blot, the eminent pteridologist and authority on the ferns Indo-China, Africa, and Madagascar.

The herbarium in Paris is one of the oldest in the world and one of the richest in specimens and in types. The oldest collection is reputedly that of Jehan Girault de Lyon, which contains 310 plants of Europe mounted without order in a book of 81 pages dated 1558. The herbarium of Ulysses Aldrovandi (1522–1605), a sizeable one of about 5000 specimens mounted on 4378 pages in 17 volumes dated 1563 but begun probably ten years earlier, was formerly in the Paris Museum but was returned to the Botanical Garden of Bologna in 1815, where it now is.

The botanical garden in Paris began as the "Jardin Royal des Herbes Médicinales" by an edict of Louis XIII in 1626. The actual ground was not acquired until 1635, at which time Guy de la Brosse was appointed as Director ("Intendant"). Guy de la Brosse died not long after, in 1641, and for the next 20 years and more the garden was a subject of controversy and did not develop significantly. Fortunately, in 1665 Louis XIV found a talented administrator in Guy Crescent Fagon (1638–1718), who was first "Démonstrateur de Botanique," and later (1673) "Intendant" and (1699) "Surintendant." Fagon gathered around him three young men destined to be famous—J. Pitton de Tournefort (1656–1708), Sébastien Vaillant (1669–1722), and Antoine de Jussieu (1686–1758).

Tournefort was appointed "Sous-démonstrateur" in 1683. He collected plants in Spain, Portugal, England, and Holland. He became famous by his book entitled "Elémens de Botanique" (1694), which he later expanded and translated into Latin as "Institutiones Rei Herbariae" (1700), one of the most important "pre-Linnaean" works on systematic botany. The Tournefort herbarium (6480 specimens), to which was added plants from Greece, Asia Minor, and Egypt collected by his friends Louis Morin and Aubriet, was meticulously mounted in books and carefully labelled; it is one of the chief treasures of the Museum.

Sébastien Vaillant, born near Pontoise in 1669, was a student of Tournefort, who placed him in charge of the cultivated plants in the Paris Garden. At about the same time the King established a "Cabinet du Jardin du Roi," the beginning of a botanical museum to accommodate the accumulating herbaria. Vaillant collected widely and made excellent botanical specimens, which were bought by Louis XV from Vaillant's widow in 1722 and placed in the "Cabinet," where they are now perhaps the oldest sheets separately mounted and distributed in the general herbarium; the older collections were all mounted on sheets in books, usually so firmly that they are still well-attached, unlike some recently glued specimens in various institutions. He is reputedlv the first to demonstrate sexuality in plants in 1716. Vaillant's principal published work is his "Botanicon Parisiense" (posthumous), perhaps the earliest "Flora" of the environs of Paris.

Antoine de Jussieu, a young M.D. from Lyon, was only 23 at the time he was appointed by the King, on Fagon's recommendation, as Démonstrateur of the Jardin du Roi. He was the first of a notable family of French botanists. His brother Bernard de Jussieu (1699–1776) was appointed Sous-démonstrateur in 1732. Bernard had an unusually modern view regarding taxonomy, that plants ought not to be classified in the basis of a single character but that all characters ought to be used, at the same time affirming that all characters do not have equal value in classification, seemingly an obvious fact, but one not always appreciated by early botanists, or even some present-day ones. Another brother, Joseph de Jussieu (1704–1779), provided Paris with one of the most important early plant collections from Peru.

In 1739 Louis XV appointed Georges Louis Marie Le Clerc de Buffon as Intendant, a famous naturalist who had a lasting influence on the development of the garden. He accumulated so many collections that it was necessary to take over the whole of the old chateau to accommodate them. Buffon extended the area of the garden on all sides and down to the Seine, including in 1780 the Abbaye Saint-Victor; a portion of this structure still stands and forms the oldest part of the present establishment, except for some trees planted by Vaillant and Antoine de Jussieu.

After the death of Buffon and after the revolution of 1788 the name of the Jardin du Roi was changed to the Jardin des Plantes, and the museum functions of the "Cabinet du Roi" became the Muséum d'Histoire Naturelle. The library, formerly accessible to only a privileged few, was opened to the public in 1794. The garden and museum survived the difficulties of the republic and and were saved from any harm by the Prussian armies in 1814 by the intervention of the powerful Alexander von Humboldt. In fact, the King of Prussia and the Emperors of Russia and Austria visited the garden in person.

After the death of Antoine de Jussieu, Louis LeMonnier (1717–1799), for whom the genus *Monniera* L. is named, was appointed to his position as Professeur. LeMonnier, a physician of Louis XV, was apparently not much of a botanist so far as published work is concerned, but he did build up a large personal herbarium of over 10,000 specimens of the most valuable kind, including those of Michaux (Levant, United States), Desfontaines (Atlas Mountains), Aublet (Guiana), Commerson (around the world) and de la Billardière (around the world). Unfortunately for Paris, the LeMonnier herbarium was acquired by Delessert and is now in Geneva.

On the recommendation of Buffon, LeMonnier was replaced in 1786 by Desfontaines, who formed the general herbarium by uniting the previous separate collections assembled by Tournefort, Vaillant, and Jussieu. At this time the herbarium consisted of about 12,000 specimens contained in 165 cartons. Desfontaines appointed Jean Baptiste Antoine Pierre Monnet, Chevalier de la

Marck (1744–1829) as the first curator specifically charged with the care of the herbarium. Lamarck, as he is generally known now, had already made a name by the publication of his monumental "Flore Française" (1778), which contains over 1,700 pages in three large volumes, and had begun the compilation of his even larger "Encyclopédie Méthodique" (1783–1817). Lamarck's personal herbarium, consisting finally of over 19,000 specimens of his own collecting and from DeCandolle, Aublet, Cavanilles, Commerson, Dombey, Palisot de Beauvois, Roxburgh, and many others, was given to J. A. C. Roeper and later acquired by the University of Rostock; it was returned to Paris only toward the end of the Nineteenth Century through the efforts of M. Bureau.

The most famous, botanically prolific, and talented of the Jussieu family was Antoine Laurent de Jussieu (1748–1836), a nephew of Antoine, Bernard, and Joseph, who was appointed Professeur in 1778, and who remained in charge until his death 58 years later. He was a student of Buffon, and had already made a name for himself by his "Genera Plantarum" (1774), one of the first (and best) attempts to place plants in natural families. He later published more than 60 memoirs on various genera and families.

A. L. de Jussieu was succeeded in 1836 by his son Adrien de Jussieu (1797–1853), a specialist principally on the family Malpighiaceae. After the death of Adr. Jussieu, as his name is usually abbreviated to distinguish him from the two other Jussieu's (A. Juss., and A. L. Juss.), the Chair of Botany was abolished for 20 years and botany was in charge of the palaeontologist Alcide d'Orbigny. During this period of the Second Empire, the herbarium suffered somewhat and was not significantly expanded, although the collections were maintained in good order by H. A. Weddell, and others. In 1873 under the Third Republic the professorship of botany was reestablished and Edouard Bureau (1830–1918) was chosen as Professeur in 1874. He and his successor H. Lecomte were extremely active in building up the herbarium to the point where it is now nearly as large as any.

The botanists who have been in charge of the living plants in the garden, as opposed to the herbarium botanists, have included many notable workers, beginning with J. A. Thouin (1745–1764), and continued by André Thouin (in charge from 1764 to 1824, quite an exceptional tenure of 60 years on the job!). He was succeeded by L. A. G. Bosc (1825–1828), known in the United States for his collection in the southern states, and then by the celebrated Charles Francois Brisseau de Mirbel (from 1828 to 1850), well-known for his "Eléments de Physiologie végétale et de Botanique." Mirbel was succeeded by another famous botanist, Joseph Decaisne, who had been "Aide-naturaliste" in the Muséum from 1833, and who was the "Professeur de Culture" or "Chief Gardener" from 1850 to 1884, another long tenure of 51 years. His "Jardin fruitier au Muséum" is an excellent example of early scientific horticulture. Subsequent Chief Gardeners have been less well known as botanists, until the appointment of André Guillaumin in 1932. Some of the well-known assistants were Spach from 1829 to 1854, Naudin from 1854 to 1872 (credited with having discovered the laws of genetics independently from Mendel and at about the same time), Deherain from 1872 to 1880, and Vesque from 1880 to 1886.

Working on the ferns in the Paris herbarium is fascinating. One never knows what may be found because the collection is one of the richest in the world in types. The collections have never been carefully studied or annotated, except for French Equatorial Africa, Madagascar, and Indo-China. Even those from French Guiana, extremely numerous, have not been looked at critically. Lemée's "Flore de la Guiane" is extremely incomplete and otherwise unsatisfactory. It is especially exciting to see the numerous types of species described by Fée from Guadeloupe, Martinique, and Brazil. Fée's handwriting is flowery and easily recognized, especially in the way that he makes the capital "F" for his own name. Fée worked partly from specimens in the Paris herbarium, and those with the names in Fée's own hand are usually holotypes or syntypes; there are often also isotypes and isosyntypes. In general there are more duplicates among the ferns in the Paris herbarium than in any herbarium I have ever seen, sometimes ten sheets or more of a single collection. This has come about by numerous originally private herbaria gravitating through long years to Paris by bequests as the original owners died and the collections were of no interest to their descendents. These herbaria have mostly been added to the general herbarium without checking to see if the specimens are duplicates or not, which was perhaps inevitable since checking in such a large herbarium would be impossibly time-consuming, and unfortunately the Museum in Paris has always apparently been somewhat understaffed. Although many of Fée's types are at Paris, most of those from Cuba and Mexico are not there. Presumably they are only in Fée's own herbarium, which is thought to have been lost. However, I have recently had an intimation that the Fée Herbarium is actually in the museum in Rio de Janeiro housed in cartons just as it was received in the latter half of the Nineteenth Century. So far as I know, it has not been examined to see if the missing types are really in the collection. At the present time it is not in suitable condition for loans to be made, and so an examination on the spot is indicated, a project that I would be interested in if funds are ever available for the trip.

One of the more recent acquisitions in Paris is the Christ Herbarium, very rich in types from Costa Rica and various parts of the Old World, especially Korea and China. Not all of Christ's types are in Paris. Some are in Basel. Dr. Holttum told me not long ago that he visited Basel and found the collections of the Sarasin brothers still in folders as Christ left them in 1897 after the publication of the "Filices Sarasinianae."

In my own work in Paris, I have concentrated chiefly on ferns from the Western Hemisphere. It is slow going, because of the mass of material and the fact that the types are generally not indicated but have to be identified. Even though I spent over two months at work in 1954 and have visited the Museum several times since for weeks at a time, still I have hardly begun. The genera of Polypodiaceae are arranged alphabetically. I have examined the historical herbaria and the general herbarium from

A to E (American specimens only), which leaves a long way to go. So far I have 4,104 photographs of types or possible types in Paris. Unfortunately, many of these are as yet unstudied and unlabelled.

The number of important collections in Paris are far too numerous to mention. The historical and special herbaria include those of Michaux, Humboldt and Bonpland, Lamarck, Jussieu, Baillon, Desfontaines, Haller (?), Cosson-Durand, Drake, Pierre, and Glaziou. There is a special herbarium of Paris, and a large one of France, the basis of which was the gift of 460 cartons from A. P. DeCandolle in 1832. Special herbaria are maintained for Madagascar, New Caledonia, and other regions under study by French botanists.

The fern collections are surely as important as those of any group of plants. They include the holotypes or isotypes of many of the species described by Fée, Gaudichaud, LaBillardière, Palisot de Beauvois, DuPetit Thouars, Bory, and other French botanists, and also the large private herbarium of Prince Roland Bonaparte. The extensive and most important collection of Desvaux was in private hands until fairly recently, but is now integrated into the general herbarium.

The history of the Muséum National d'Histoire Naturelle, Paris, has been given in some detail since it is not in general well known to many botanists outside of France. Most of the data have been obtained from a paper entitled "Historiques des collections de botanique du Muséum d'Histoire Naturelle de Paris," by H. Lecomte, written when he took over the professorship from Bureau. This was printed in the "Revue Scientifique" [Revue Rose], vol. 7, no. 22, June, 1907, a publication undoubtedly very rare outside of France. I am indebted to Dr. H. Heine, of the Muséum, for bringing it to my attention. For the earlier history I have also consulted the elaborate publication "Archives du Muséum National d'Histoire Naturelle, Volume du Tricentenaire" (ser. 6, vol. 12, 1935), which contains a full account of the history of the Muséum by the Director, Paul Lemoine.

(*To be continued*)

The Polypodium pectinatum-plumula Complex in Florida[1]

A. MURRAY EVANS

Although a treatment of the entire *Polypodium pectinatum-plumula* complex is in preparation for future publication, it seems appropriate, due to current efforts towards floras for the southeastern United States and southern Florida, to publish the portion of the study that applies to the representatives of the complex which occur within the continental United States.

Traditionally this complex has included only two species in Florida, *Polypodium plumula* Humb. and Bonpl. ex Willd. and *P. pectinatum* L. On the basis of a comprehensive study of the entire complex, it now appears that three taxa are present, *P. plumula, P. ptilodon* Kunze var. *caespitosum* (Jenm.) Evans, and *P. dispersum* Evans. *Polypodium dispersum* is a newly defined species, and one which has caused taxonomic confusion in the complex because it appears to be intermediate between the other two taxa. Wherry (1964, p. 62) treats it as a hybrid and indicates that its spores are aborted, which they are not; his illustration of *P. plumula* fits *P. dispersum* better than *P. plumula*, which he does not illustrate. *Polypodium ptilodon* represents what regional authors and collectors have construed as "*P. pectinatum.*" *Polypodium pectinatum* L. has long been a source of confusion, particularly in the Caribbean area, and it has been treated as consisting of numerous and variable forms. A full treatment of this problem is deferred for later publication. In summary, however, the original material on which Linnaeus based his interpretation

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[1] Contribution from the Botanical Laboratory, The University of Tennessee, N. Ser. no. 317. This paper is drawn from a larger dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at the University of Michigan, 1964. I wish to thank Dr. W. H. Wagner and Mr. C. V. Morton for their help. I also acknowledge the help of numerous field collectors and the curators of herbaria who contributed materials to this study. This research was aided by National Science Foundation Grants G-10846 and GB-3966, and a travel grant from the Rackham Graduate School of the University of Michigan.

is from the Lesser Antilles (Martinique). Only one species in this complex occurs there; it is smaller and somewhat more delicate than our Florida material, is an epiphyte, and is similar to material from Jamaica that is diploid ($n = 37$). The plants in Florida are all tetraploids ($n = 74$), are terrestrial, and exhibit consistent morphological differences from the Lesser Antillean plants. The tetraploid "*P. pectinatum*" records from Jamaica reported by T. Walker (1966) I presume to be other taxa and not *P. pectinatum* L. *sensu stricto.* Unfortunately I have not been able to see his material, but my own field and cytological studies of Jamaican *Polypodium* support my findings.

In Central and South America *P. plumula* has been broadly construed to include what are really several species. In Florida it has been correctly identified, except for the confusion with its relative *P. dispersum.*

KEY TO THE POLYPODIUM PECTINATUM-PLUMULA COMPLEX IN FLORIDA

Rachis paleae filiform and inconspicuous, deciduous; rachis dark brown; plants terrestrial or on rotten logs; veins 2- or 3-forked; spores 64 per sporangium. . . . . .1. *P. ptilodon* var. *caespitosum*

Rachis paleae cordate or hastate, conspicuous, persistent; rachis black; plants epiphytic or epipetric; veins 1- or 2-forked; spores 32 or 64 per sporangium.

  Plants usually epiphytic and drooping; fronds narrow-ovate or linear; segments linear, the basal not deflexed, reduced to mere auricles; veins 1-forked; rachis paleae cordate and appearing bullate; spores 64 per sporangium. . . . . .2. *P. plumula*

  Plants usually epipetric and erect; fronds narrow-ovate; segments narrow-ovate, the basal shorter, deflexed, occasionally reduced to auricles; veins 2-forked; rachis paleae hastate, flat; spores 32 per sporangium. 3. *P. dispersum*

1. POLYPODIUM PTILODON Kunze var. **caespitosum** (Jenman) A. M. Evans, comb. nov.

P. pectinatum var. *caespitosum* Jenman, Bull. Bot. Dept. Jamaica **4:** 125. 1897. TYPE: Jamaica, Old England, 4,000 ft, *G. S. Jenman* (NY!).

"*P. pectinatum*" *auctt., non* L.

Plants terrestrial or on rotten logs; fronds 30–105 cm long; stipe and rachis dark red-brown, ctenoid (comb-like) hairs conspicuous; rachis paleae inconspicuous, filiform, the margins entire or inconspicuously fimbriate; blades narrow- to linear-ovate, 27–90 cm long, 6.5–18 cm wide, narrowly cuneate in outline at the base; segments straight or subfalcate, acute to rounded, entire to subcrenulate, the basal ones reduced to lobes or auricles; lamina herbaceous to coriaceous, with scattered silvery acicular hairs, more densely pilose in an oblong area around the sorus; veins 2–3 (4)-forked; sori round or oblong; sporangia with 1 or 2 capsular paraphyses; spores ca. 56μ long, reniform, monolete, 64 per sporangium; $n = 74$.

Distribution: FLORIDA: Brevard, Citrus, Collier, Dade, Hernando, Highlands, Hillsborough, Lake, Manatee, Marion, Orange, Pasco, Polk, Putnam, Seminole, Sumter, and Volusia Counties. West Indies, Mexico, Honduras.

This is the most northern of the four varities of *P. ptilodon* Kunze which ranges widely over tropical America to northern Argentina. In Florida it is readily recognizable by its generally terrestrial habit, large size, blackish-brown rachis, which dries red-brown, and the very inconspicuous filiform rachis scales. The species is particularly distinct from other species in the complex because of the oblong patch of laminar hairs surrounding and exceeding the sorus.

2. **POLYPODIUM PLUMULA** Humb. & Bonpl. ex Willd. in L., Sp. Pl. ed. 4, **5**: 178. 1810.

Plants epiphytic, occasionally epipetric; fronds 20–60 cm long; stipe and rachis black, without ctenoid (comb-like) hairs; rachis paleae conspicuous, broadly cordate with a short-acuminate apex, bullate (inflated), the margins fimbriate; blades narrow- to linear-elliptic, 15–52 cm long, 3–7.5 cm wide, cuneate or subtruncate in outline at the base; segments 2–3 mm wide, straight, obtuse, entire, reduced but not deflexed at blade base; lamina herbaceous to coriaceous with scattered acicular hairs; veins 1- or 2-forked; sori round; sporangia with 3 or 4 capsular paraphyses; spores ca. 50μ long, reniform, monolete, 64 per sporangium; $n = 74$.

Distribution: FLORIDA: Brevard, Citrus, Dade, Hernando, Hillsborough, Marion, Monroe, Orange, Polk, Seminole, St.

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PLANTS OF FLORIDA

Polypodium dispersum Evans

CITRUS COUNTY: R20E, T21S, Sect. 1, Pineola Grottoes, on trunk of huge Quercus virginianum. Large soriferous colony, with gametophytes. With P. plumula and P. ptilodon var. septentrionale. 2N = 111.
Sept. 21, 1963. A. M. Evans 2008

POLYPODIUM DISPERSUM A. M. EVANS, SP. NOV.
EVANS 2008 (ISOTYPE, TENN)

John's, Sumter, and Volusia Counties. Tropical America south to southern Brazil.

This species varies throughout its range, but it is quite consistent and readily recognizable in Florida. Although primarily epiphytic, plumose, and drooping, it is occasionally found on rocks; then it is smaller, more erect, and more similar to the following species.

3. POLYPODIUM **dispersum** A. M. Evans, sp. nov. *Plate 27*

P. molle H. B. K. Nov. Gen. and Sp. **1**: 8. 1816, *non* Schreb., 1771. TYPE: Venezuela, Cumaná, *Humboldt & Bonpland* (P, fragment B!).

P. pectinatum var. *squamosum* Lindm. Ark. för Bot. **1**: 238. 1903, *non P. squamatum* L. SYNTYPES: Jamaica, *Herb. Alstroemer* (S-PA!) and *Herb. Casstroem* (S-PA!); Bermuda, *Herb. Farlow* (GH!); Brazil, Mato Grosso, Fazenda São José, *Regnell A2671* (LECTOTYPE, S!); Rio de Janeiro, *Mosén 113* (B!, S!, S-PA!).

P. microsorum Lindm. Ark. för Bot. **1**: 239. 1903, *pro parte,* as to Cuba, *Wright 1051*, but not as to the lectotype, which is *P. pectinatiforme* Lindm.

Rhizoma breviter repens, paleis anguste triangularibus rufobrunneis acuminatis paullo comosis inconspicue dentatis; frondes approximatae, rhachibus quam stipitibus ca. triplo longioribus, nigris, parce pilosis, pilis acicularibus vel interdum ctenoideis, paleis conspicuis anguste triangularibus hastatis non bullatis atro-rufo-brunneis basi pallida excepta, inconspicue dentatis basi fimbriatis; lamina anguste triangularis basi subtruncata vel abrupte cuneata, segmentis horizontalibus, infimis interdum deflexis reductis, herbaceis, apice obtusis, basi symmetricis, integris, pilis clavatis et longe acicularibus parce praeditis; costae decurrentes, parce pilosae, pilis acicularibus, parce paleaceae; venae bifurcatae, liberae; sori mediales, rotundi vel interdum oblongi, paraphysibus paucis simplicibus clavatis; sporangia plerumque setosa; sporae 32.

Plants epipetric, occasionally epiphytic; fronds 27–63 cm long; stipe and rachis black, occasionally with ctenoid hairs; rachis paleae conspicuous, narrow-triangular, hastate, acuminate, nonbullate, inconspicuously toothed, fimbriate at the base; blades narrow-ovate to narrow-triangular, 17–48 cm long, 4.5–9 cm wide, subtruncate to abruptly cuneate in outline at the base; segments 3–6 mm wide, straight, obtuse, entire, reduced (sometimes to mere lobes) and occasionally deflexed at the blade base; lamina herbaceous, with scattered acicular hairs; veins 2-forked; sori round or occasionally oblong; sporangia mostly with 2 (1–4) capsular paraphyses; spores ca. 43μ long, globose to ovoid, with irregular, incomplete or interrupted, variable scar, 32 per sporangium; $n = 111$ (apogamous).

TYPE: Florida, Citrus Co., R20E, T21S, Sect. 1, Pineola Grottoes, Sept. 21, 1963, *A. M. Evans 2008* (MICH; isotypes TENN, US).

Distribution: FLORIDA: Alachua, Brevard, Citrus, Hernando, Hillsborough, Marion, Martin, Monroe Counties. Tropical America south to southern Brazil.

The details of apogamy in this species vary from cases of apogamy known in other ferns (Evans, 1964b). One of the distinctive features is that all the sporangia have 32 viable spores per sporangium, contrary to most apogamous ferns which have either some sporangia with aborted spores or many spores aborted within any given sporangium. Gametophytes, both wild and cultured, mature quickly and may produce two or three apogamous sporophytic proliferations, but neither functional nor aborted sex organs occur.

Polypodium dispersum is commonly found in areas of exposed limestone outcrops, often in dense mats on the rocks. It is often found in a juvenile, non-soriferous state, and usually spreads extensively by new rhizomes budding from the roots of larger plants. This condition has been found in several other tropical American epipetric or epiphytic species of the *P. plumula* group (Evans, 1964a), as well as in various other members of the Polypodiaceae, Aspleniaceae, Grammitidaceae, and Vittariaceae. Root budding appears to be correlated with the exposure of the roots in these typically epiphytic or epipetric ferns. Two populations of *P. dispersum* growing in apparently marginal habitats in Florida suggest that root proliferations are a means of perpetuating a population in the absence of conditions suitable for production of fertile plants. One of these is at "Buzzard's Roost," in Alachua County, the northern limit of the range. Although there are moist grottoes in this area, the plants grow on limestone outcrops scattered through open woods. The plants are non-soriferous and mostly under 10 cm tall, although the species is usually at least twice that tall. Dr. Ernest Ford, of the University of Florida, has observed these plants becoming smaller over the years, and recently he has seen no fertile plants. Living specimens collected from the area have been grown to maturity in the greenhouse.

Another marginal locality is Pumpkin Key, in Monroe County, a low coral island off the northwestern tip of Key Largo. This Key is only about 1,100 feet in diameter and has a maximum elevation of approximately 11 feet. It is unusual among the small keys because it does have a small mahogany (*Swietenia mahagoni*) and Gumbo Limbo (*Bursera simaruba*) hammock in the center of the island. Herbarium specimens of this *Polypodium* had been collected here by J. K. Small in 1915 and 1920. I have seen no collections made since, and I was assured that it probably no longer grew there. I visited this island in April, 1963, with Doctors C. E. Delchamps and S. M. Faber, of the University of Miami, and found many hundreds of tiny, juvenile plants growing in the hammock on exposed coral and particularly on large, fallen mahogany logs. The plants were all interconnected by long roots running over the surface of the logs; no fertile plants were seen. The collections by Small were similar. Presumably Small searched the small area well and also found no fertile material. Plants collected at this locality have also been brought to mature fruiting condition in the greenhouse. These observations suggest that this species has been able to exist many years in a juvenile, vegetative condition in this marginal locality.

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Exclusion of the New York Fern and the Hay-scented Fern from the Flora of Iowa

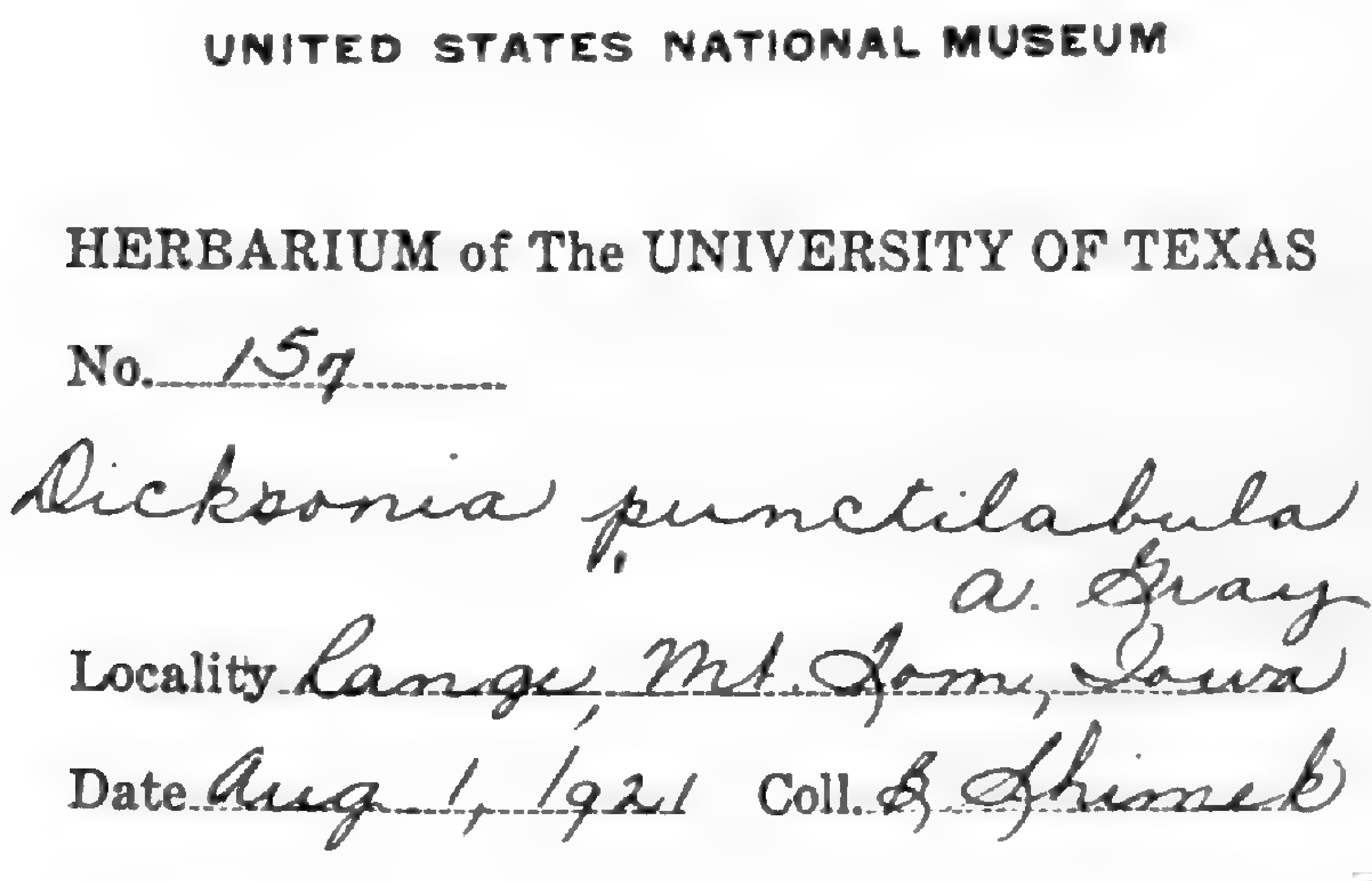
T. S. COOPERRIDER

It is always tedious to remove errors from floristic literature when they involve a species' distribution range. The present case may prove particularly difficult because the errors are supported by herbarium specimens.

The problem concerns a group of fern specimens in the U. S. National Museum purportedly collected by B. Shimek in Iowa. Some of the specimens were called to my attention by C. V. Morton, who examined them while preparing a review (Morton, 1961) of my publication (Cooperrider, 1959) on the pteridophytes of Iowa. In that work I excluded the New York Fern, *Thelypteris noveboracensis,* reported by Tuttle (1920) from Mitchell County, Iowa. Miss Tuttle was not noted for accuracy of identification, and since no specimens had been found in Iowa herbaria, the action seemed justifiable. Morton, however, found a specimen at US, accurately determined and attributed to Iowa. Later, R. M. Tryon inquired about the absence of the Hay-scented Fern, *Dennstaedtia punctilobula,* from my Iowa publication. He had included Iowa in its distribution range (Tryon, 1960) on the basis of a specimen at US.

The specimens in question are these (listed in order of their US accession numbers): *Aspidium cristatum* Sw., Cummington Iowa, Aug. 16, 1921, *B. Shimek 25* (US 1,871,909); *Phegopteris polypodioides* Fée, Cummington, Iowa, Aug. 19, 1921, *B. Shimek 41* (US 1,871,910); *Aspidium noveboracense* Sw., Ravine, Tom Range, Iowa, July 22, 1921, *B. Shimek 152* (US 1,871,911); *Dicksonia punctilobula* A. Gray, Range, Mount Tom, Iowa, Aug. 1, 1921, *B. Shimek 157* (US 1,871,912); and *Aspidium marginale* Sw., Cliffs, Mount Tom, Iowa, Aug. 9, 1921, *B. Shimek 225* (US 1,871,914).

It is my contention that the specimens were collected in Massachusetts by some person other than Shimek. All the labels have the heading "HERBARIUM of The UNIVERSITY OF TEXAS," and presumably were distributed by that herbarium. All the specimens were accurately determined; the currently used names are, respectively: *Drygpteris cristata* (L.) Gray, *Thelypteris phegopteris* (L.) Slosson, *Thelypteris noveboracensis* (L.) Nieuwl., *Dennstaedtia punctilobula* (Michx.) Moore, and *Dryopteris marginalis* (L.) Gray. It should be noted that the two *Dryopteris* species



UNITED STATES NATIONAL MUSEUM

HERBARIUM of The UNIVERSITY OF TEXAS

No. 159

Dicksonia punctilabula
A. Gray

Locality Range, Mt. Tom, Iowa

Date Aug. 1, 1921 Coll. B. Shimek

❶

Very sincerely,
B. Shimek
B.Shimek

B. Shimek

❷

FIG. 1. PHOTOGRAPH OF SPECIMEN LABEL. FIG. 2. TWO AUTHENTIC SHIMEK SIGNATURES.

and *Thelypteris phegopteris* do occur in Iowa but are rare in that state (Cooperrider, *op. cit.*).

Mount Tom is a well known site a few miles north of Holyoke, Massachusetts; the town of Cummington is 25 miles distant. Recent visits to the area disclosed that the first two species listed above are common in Cummington and the last three are common at Mt. Tom. Specimens of each (respectively, *Cooperrider* and *Brockett 10749, 10748, 10638, 10747*, and *10637*) are now at KE.

Bohumil Shimek was for many years curator of the herbarium at the University of Iowa, and collected widely in that state. Dr. Henry S. Conard, who prepared a biography of Shimek, writes in personal communication: "I did not find any record that he [Shimek] was ever in Massachusetts." Examination of Shimek's field notebooks and specimens at the University of Iowa revealed that he was collecting in Allamakee and Clayton Counties, Iowa, on August 5, 8–9, and 18–20, 1921. I have been unable to locate a Cummington or a Mount Tom in either of these counties, or elsewhere in Iowa. A comparison of the handwriting on the specimen labels (*Fig. 1*) with that of authentic Shimek signatures (*Fig. 2*) shows clearly that the labels were not prepared by him.

The origin and history of the specimens is speculative. They may well have been sent from Iowa to The University of Texas, where someone wrote the erroneous labels. In any event, they were not collected in Iowa by Shimek. *Dennstaedtia punctilobula* and *Thelypteris noveboracensis* must continue to be excluded from the known flora of Iowa, and Iowa excluded from the known range of these species.

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Shorter Notes

THE IDENTITY OF POLYPODIUM SALICIFOLIUM VAHL.—Carl Christensen (Ind. Fil. 561. 1906) lists *Polypodium salicifolium* Vahl (Ecolog. Amer. **3:** 31. 1807) as a dubious species, presumably because he did not see a type or other authentic specimens. While identifying a lot of specimens from the Botanical Museum and Herbarium, Copenhagen, Denmark, Mr. Morton and I discovered the type of this species, a specimen from Montserrat collected by Ryan. The specimen is obviously *Thelypteris angustifolia* (Willd.) Proctor. Because Vahl's name antedates *Meniscium angustifolium* Willd. in L. (Sp. Pl. ed. 4, **5:** 133. 1810), the epithet *salicifolium* would displace the well-known *angustifolium* if it were transferred to *Thelypteris*. However, there is an Old World species of *Thelypteris*, until recently called *Dryopteris salicifolia* (Wall. ex Hook.) C. Chr., which would need a new epithet if Vahl's name were transferred to *Thelypteris*. The combination *Thelypteris salicifolia* (Wall. ex Hook.) Reed, Phytologia **17:** 311. 1968 preserves the present usage of these epithets.—DAVID B. LELLINGER, *U. S. National Museum, Washington, D. C. 20560.*

ASPLENIUM TRICHOMANES NEW TO NEWFOUNDLAND.[1]—An examination of specimens filed as *Asplenium viride* in the herbarium of the Canada Department of Agriculture, Ottawa, has revealed one of *A. trichomanes* L., which was found on the southerly slopes of a dry, serpentine ridge near the head of the North Arm, Humber District, Newfoundland, on July 18, 1950 (*E. Rouleau 888*, DAO). North Arm is the northern arm of the Bay of Islands on the west coast of Newfoundland. It is approximately 20 miles north of the city of Corner Brook, which is situated on the southern arm of the same bay. This collection is a most interesting northeastward range extension of some 250 miles from Cape Breton Island, Nova Scotia. Rimouski County, Quebec (the

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[1] Plant Research Institute Contr. No. 677.

closest locality cited by Fernald in "Gray's Manual") is about 500 miles west of this site. Roland[2] reported *A. trichomanes* in Nova Scotia "from Kings, Cumberland, Guysborough and Inverness Co[untie]s. Scattered records exist for other localities in the province." The following records from Victoria County, which lies adjacent to Inverness County on Cape Breton Island, are also noteworthy: Abundant on wet cliff, Gray Glen Brook, *Smith et al. 4442* (DAO); very abundant on dry cliff crevices, Lockhart Brook, Salmon River, *Smith et al. 7924* (DAO); abundant, top of boulder slope, Rocky Brook, *Smith et al. 7971* (DAO).—W. J. CODY, *Plant Research Institute, Research Branch, Canada Department of Agriculture, Ottawa, Canada.*

THE CORRECT NAME FOR THE BUTTON FERN.—Among the few species of *Tectaria* in cultivation in the United States, only one is gemmiferous. It has been identified[1] as *T. cicutaria* (L.) Copel., a West Indian species, which it resembles in its pinnate-pinnatifid to bipinnate-pinnatifid fronds. It is not that species, however, but is identical with *T. gemmifera* (Fée) Alston. I have compared a specimen of the Button Fern grown by Mrs. MacFadden with several specimens of this east African species which I borrowed frem Kew. The hairs on the underside of the blades of *T. cicutaria* are long, their cells are longer than broad, and they are found on the laminar tissue as well as on the axes and veins. There are no buds (gemmae) on the rhachises or costae. *Tectaria gemmifera* has much shorter hairs, with the cells about as long as broad, and the hairs are confined to the axes and veins. Numerous buds are present on the rhachises and costae. These bear many, thin, lanceate-auriculate, ciliate scales; in the few specimens I have seen none have produced plantlets while attached to the mother plant.—D. B. LELLINGER, *U. S. National Museum, Washington, D. C.* 20560.

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[1] Joe, Barbara. 1964. Ferns cultivated in California: Tectaria. Baileya **12**: 47–51.

[2] Roland, A. E. 1947. Flora of Nova Scotia. Proc. Nova Scotian Inst. Sci. **21**(344): 95–642.

MECODIUM WRIGHTII ON VANCOUVER ISLAND.—On Vancouver Island, British Columbia, we discovered *Mecodium wrightii* (v. d. Bosch) Copeland, while we were involved in field studies of the ecology of *Picea sitchensis* (Bong.) Carr. We collected material from three stations between Clayoquot Sound and Barkley Sound on the west coast of the island (approx. 49°N, 126°W). These collections extend the range of this species approximately 400 miles southward along the west coast of North America. The more northern collections have been described by Taylor.[1] Our material consists entirely of male gametophytes with antheridia. They grow consistently on decaying wood or old bark of Sitka spruce. All populations are within 500 m of the Pacific Ocean beach at altitudes of 5–50 m in the Coastal Western Hemlock biogeoclimatic zone.[2] This habitat contrasts with that of the previously reported North American collections, all of which came from either humid cliff crevices or on soil in shaded sites, particularly stream canyons. Collections from mainland northern British Columbia came from the bark of *Chamaecyparis nootkatensis* (D. Don) Spach (W. B. Schofield, pers. comm.).

Specimen data are: Wickaninish Bay, 1 mile NW of Green Point on SW facing slope in Sitka spruce forest on decaying wood, coll. no. Co-501; east side of Lemmens Inlet on NW facing slope in Sitka spruce—western hemlock forest near a small mountain stream, growing on the base of Sitka spruce, coll. no. Co-607; NW end of Florencia Bay on NE facing slope in Sitka spruce forest growing on decaying wood, coll. no. Co-6601. All collections are in UBC.[3]—LAWRENCE D. CORDES AND VLADIMIR J. KRAJINA, *Department of Botany, University of B. C., Vancouver, B. C., Canada.*

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[1] TAYLOR, T. M. C. 1967. Mecodium wrightii in British Columbia and Alaska. Amer. Fern J. **57**: 1–6.

[2] KRAJINA, V. J. 1965. Biogeoclimatic zones and biogeocoenoses of British Columbia. Ecology of West. N. Amer. **1**: 1–17.

[3] Field studies were supported by the National Research Council of Canada Grant No. A-92, to V. J. Krajina.

THE PROPER AUTHORITIES AND CITATIONS FOR DRYOPTERIS ARGUTA AND D. SPINULOSA.—The common Californian Shield-fern, *Dryopteris arguta*, has commonly been given the authority "(Kaulf.) Watt, Canad. Nat. II, 3: 159. 1866." In checking Watt's publication, I found that the combination is not validly published here. Watt gave a catalogue of northern North American ferns, and recognized the genus *Aspidium* Swartz in a broad sense, including *Polystichum* and *Dryopteris* as sections. Although Watt writes "*D. arguta* (Kaulf. 242)," he did not in fact recognize *Dryopteris* as a genus at this time, and therefore the "*D.*" must be disregarded and read as "*A.*"

Most early writers on ferns considered *Aspidium argutum* Kaulf. as only a variety of the southern European *A. rigidum* (Hoffm.) Swartz [= *Drypoteris rigida* (Hoffm.) Underw.]. Apparently the first to use the name *Dryopteris arguta* was Christensen in his paper "On the Genus *Dryopteris*" (Amer. Fern J. **1:** 36. 1911), but he did not give any citation or any authority for the epithet, and so although the meaning is really clear the combination can hardly be considered as validly published by Christensen. The first to use definitely the name *D. arguta* was Maxon in his paper "Notes on American Ferns—XVI." Maxon gave a clear statement of the characters of *D. arguta*, and its specific distinctness has hardly been questioned since, but Maxon erroneously attributed the combination to Watt, in which he has been followed by more recent authors. The proper citation is:

DRYOPTERIS ARGUTA (Kaulf.) Maxon, Amer. Fern J. **11:** 3. 1921.
Aspidium argutum Kaulf. Enum. Fil. 242. 1824.

In the Index Filicum Supplement 3, the citation of "Watt, Canadian Naturalist II, **13:** 159. 1867" for *D. spinulosa* is wrong as to volume, page, and date. Like *D. arguta* mentioned above, this combination was not properly validly published on p. 159 of vol. 3 (not 13), but was published later in the same volume. Apparently Watt changed his mind about adopting *Dryopteris* as a genus distinct from *Aspidium*. The proper citation is:

DRYOPTERIS SPINULOSA (Müll.) Watt, Canad. Nat. II, **3:** 403. 1868.
Polypodium spinulosum Müll. Fl. Dan. *t. 707*. 1777.

Although the name *D. spinulosa* is still commonly used in the eastern United States it is incorrect, because the basionym of Müller is a later, illegitimate homonym of *Polypodium spinulosum* Burm. (1768). The correct name for our plant is *Dryopteris carthusiana* (Vill.) H. P. Fuchs, Bull. Soc. Bot. France **105**: 339. 1958.—C. V. MORTON, *U. S. National Museum, Washington, D. C. 20560.*

Notes and News

XITH INTERNATIONAL BOTANICAL CONGRESS.—About six thousand botanists are expected to attend the next international botanical congress, which will be held in Seattle, Washington, next August. Many fern enthusiasts may wish to register and to attend the sessions of contributed fern papers. Several pre- and post congress field trips are also planned. The Society is planning a luncheon that will be an excellent opportunity to meet pteridologists from at home and abroad. A meeting of the Council will also be held. These activities will take the place of those normally scheduled with the A.I.B.S. annual meeting. For details concerning the papers and field trips, write to Dr. George W. Fischer, 3917 15th Ave. N.E., Seattle, Washington 98105. If you wish to attend the luncheon, write to the Society president soon, as an estimate of the number likely to attend is needed.—I. W. K.

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Manuscripts should have ample margins and should be typed double-spaced throughout, including the title, bibliography, and footnotes. Footnotes and tabular matter should be kept to a minimum. Reports of chromosome numbers will not be published unless documented by voucher specimens deposited in some herbarium.

Reprints should be ordered when galley proof is returned to the editor. An order blank will be included with the galley proof.

The payment or non-payment of page charges by authors' institutions or grants will affect neither the acceptability of manuscripts for publication nor the date of publication.

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Richard Eric Holttum, Distinguished Pteridologist

Warren H. Wagner, Jr.

At the age of 73, Dr. R. E. Holttum has behind him a career of accomplishment that few botanists can emulate; we hope that he will continue his productive research for many years. His delightful letters to pteridologists in many parts of the world and his readiness to help in knotty problems of nomenclature and taxonomic interpretation are known to many of us. In world renown he is the outstanding senior pteridologist.

Dr. Holttum was born on July 20, 1895, in Linton, Cambridgeshire, England. He received his education at Cambridge University, where he was awarded the B.A. degree in 1920, the M.A. in 1927, and the Sc.D. in 1951. He also received an Honorary Sc.D. from Singapore in 1954. We associate his career largely with Malaya, where he went in 1922 to serve as the Assistant Director of the Gardens Department, Straits Settlements, which was renamed the Botanic Gardens, Singapore. After three years he was made the Director and in 1949 Professor of Botany at the University of Malaya. He remained in Malaya until 1954, returned to England in 1949, and since then has been engaged in active research at the Royal Botanic Gardens, Kew. He lives with his wife at 50 Gloucester Court, Kew Road, Richmond, Surrey, England, where he is visited by pteridologists from many countries.

No "closet botanist," Dr. Holttum is an active field worker and has had a long acquaintance with plants in their natural state. He made his first large expedition in 1921 to Greenland with Professor Seward. When he arrived in the tropics he began a series of field explorations which lasted through 1954. During this time he learned much tropical biology and discovered many new

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plants. In addition to numerous trips in the Malay Peninsula, he visited Sumatra, Western Java, British North Borneo, and other places. Because of this experience he was able to write knowingly on the ferns and other pteridophytes of other areas, such as Thailand and the islands of the western Pacific.

His extensive work on pteridophytes is summed up in over 100 papers and books. He described many new species and genera of ferns and did revisional work on a large number of genera, including *Lindsaea*, *Stenochlaena*, *Lomariopsis*, *Teratophyllum*, *Cyathea*, *Lomagramma*, *Diplazium*, *Arcypteris*, *Pleocnemia*, *Heterogonium*, and *Thelypteris*. Notable among his contributions are his writings on the ecology of ferns, based upon his first-hand knowledge and observations in the natural habitats. His chapter on "Fern Ecology" in Verdoorn's "Manual of Pteridology" is a classic reference. He, like F. O. Bower, E. B. Copeland, R. C. Ching, and a number of others, has grappled with the broad problem of classification of ferns, and his system of relationships and classification, first published in 1947, has been very influential in shaping our ideas of phylogeny in these plants. Many of his writings focus on problems of relationships within particular groups. For example, he has correlated growth habit and classification in the Gleicheniaceae. He was among the first to exclude the curious genus *Platyzoma* from the Gleicheniaceae; he placed it correctly among the gymnogrammoid ferns. His recent studies on the Cyatheaceae are outstanding. In a series of penetrating papers he has shown more clearly than before the interrelationships of the large tropical complex of tree-ferns.

Dr. Holttum has also contributed much to the stability of fern nomenclature and is frequently consulted on problems of correct naming. In addition to his basically pteridological research, he has produced books on other botanical subjects: "Plant Life in Malaya," "Orchids of Malaya" (both in 1954, the latter having appeared in three editions), "Zingiberaceae of the Malaya Peninsula" (1950), and "Bamboos of the Malaya Peninsula" (1958). His book "Ferns of Malaya" (1954) is a major contribution to pteridology in the Old World tropics.

Dr. Holttum has only rarely visited the United States. In the winter of 1959 he spent six weeks at the University of Michigan and several weeks at the National Herbarium studying type materials and other fern collections there.

Dr. Holttum has received many honors. He has been president of various societies, including the Singapore Gardening Society (1937–39, 1947–53), the Singapore Rotary Club (1939–41), and the Section for Botany of the British Association for the Advancement of Science (1961). He was President of the British Pteridological Society from 1960 to 1963. He was awarded the Linnaean gold medal in 1964. He has been commemorated in plant names, such as the tree *Sterculia holttumii* Ridley and the generic name for the gymnogrammoid fern, *Holttumiella flabellifolia* (Baker) Copeland.

It is highly fitting that this distinguished pteridologist has now been elected to Honorary Membership in the American Fern Society.

BOTANICAL GARDENS, UNIVERSITY OF MICHIGAN, ANN ARBOR, MICH. 48105.

On the Distribution and Ecology of Ceratopteris in Surinam

J. VAN DONSELAAR[1]

In his preliminary revision of the genus *Ceratopteris* Benedict (1909) distinguished four species: *C. thalictroides* (L.) Brongn., *C. pteridoides* (Hook.) Hieron., *C. deltoidea* Benedict, and *C. lockhartii* (Hook. & Grev.) Kunze. Two more names were said to deserve further investigation: *C. cornuta* (Palisot) LePrieur and

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[1] I am indebted to the Foundation for Scientific Research in Surinam and the Netherlands Antilles, which organized the investigations in the Brokopondo area; to the Netherlands Foundation for the Advancement of Tropical Research (WOTRO), which financed these investigations; and to Dr. K. U. Kramer, who identified the ferns and critically reviewed the manuscript.

C. gaudichaudii Brongn. Since then the first four have not been in dispute, *C. cornuta* has become generally recognized, and *C. gaudichaudii* has remained doubtful (Fosberg, 1958).

Most of the species of *Ceratopteris* are widely distributed. *Ceratopteris thalictroides* occurs in tropical Asia, Australia, and America (Benedict, 1909; Morton, 1967). *Ceratopteris pteridoides* is known from tropical America, subtropical South America, and continental tropical and subtropical eastern Asia (De Vol, 1957). *Ceratopteris deltoidea* is now known only from Florida, Central America, Jamaica, Porto Rico, Guyana, and Surinam. It has probably disappeared from Louisiana (Benedict, 1909; De Vol, 1956). *Ceratopteris lockhartii* is known from Trinidad, Guyana, and French Guiana (Benedict, 1909), *C. cornuta* from tropical and subtropical Africa, and *C. gaudichaudii* from Guam.

Three of the species have been collected in Surinam, and will be discussed in detail. *Ceratopteris lockhartii*, which has not been reported since Benedict (1909), is to be expected, and has been found in Guyana and in French Guiana. The following notes on the distribution and ecology of *Ceratopteris* in Surinam are based on literature, herbarium specimens at Utrecht, and on personal observations made from 1964 to 1966.

Ceratopteris thalictroides occurs generally in the swamps of the coastal area. Lindeman (1953, Table I col. 2 & 3 and p. 120) presented two vegetation records from the Nickerie district, with *C. thalictroides* erroneously cited as *C. deltoidea*. This vegetation, occurring in 10–20 cm of oligohalinic water (wet season) over a layer of 10 cm of peat on clay, is dominated by *Eleocharis mutata* or *Cyperus articulatus* with the *Eleocharis* as co-dominant species.

During the severe dry season of 1964, large areas of swamp forest in the Perika River area burned, and even thick layers of the peat soil were destroyed by the fire. *Ceratopteris thalictroides* penetrated into the newly formed open water from the shallow ditches traversing this area. Both in the ditches and in the new habitat it occurs now in 20–60 cm of water during the rainy season, whereas in the dry season there may be hardly any water or even no surface water with just a soaked substrate.

The main vegetation types in which *C. thalictroides* occurs are (1) floating patches of *Salvinia auriculata* or *Utricularia* sp., (2) floating mats dominated by *Jussiaea leptocarpa*, and (3) vegetation rooted in shallow water, principally of *Calathea comosa*. In all cases the ferns float or are rooted, but in none can they drift freely, because either the water is too shallow, the locality is too sheltered, or they are confined by a dense growth of other plants. Other records from northern Surinam agree with the above data.

Outside of Surinam the species has been observed mainly rooting in mud or floating in shallow water (Benedict, 1909; Backer and Posthumus, 1939, p. 252; Copeland, 1958, pp. 164-165; Fosberg, 1958).

Ceratopteris pteridoides is also one of the common species of wet habitats in northern Surinam. Lindeman (1953, Table I col. 19 and p. 121) described a swamp vegetation from the Nickerie district with *Leersia hexandra* as the main species growing in 20–30 cm of oligohalinic water during the wet season.

Another series of observations made in 1964–66 is also available concerning the behavior of this fern in the area of the artificial Brokopondo Lake in central Surinam (van Donselaar, 1968). In a stagnant branch of the small Soekroewatra Creek, *C. pteridoides* rooted in the mud, primarily with a blue-flowered member of the Scrophulariaceae tentatively identified as a species of *Bacopa*, and also with *Panicum repens, Jussiaea affinis, Nymphaea* sp., and *Lemna valdiviana*. When the dam in the Surinam River was closed on February 1, 1964, and the lake began to form (Leentvaar, 1966a[2], 1966b; van der Heide, 1967), this vegetation was lifted by the rising water, and after a while only those species that could float, *C. pteridoides* and *Lemna valdiviana*, survived. From this and several other nuclei *C. pteridoides* began to spread over the expanding lake. The success of *C. pteridoides* varied greatly and unpredictably, but in general the populations were densest

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[2] Leentvaar reported *C. thalictroides* in the lake and published (1966b) a map showing its distribution at the end of 1964, but his data actually apply to *C. pteridoides*.

where the trees still retained their leaves and offered some shade (the shallow lake basin had not been cleared beforehand). At its maximum in April, 1966, *C. pteridoides* colonized 17,000 hectares (42,000 acres). Its distribution appeared to be influenced greatly by the prevailing easterly to south-easterly winds. By December, 1966, the quantity of *C. pteridoides* appeared to have diminished considerably; only scattered patches were observed. Possibly control of the Water-hyacinth, *Eichhornia crassipes*, the most abundant plant in the lake, affected the *Ceratopteris* because in many places it offered shelter. Another factor may have been the increased light intensity as more and more inundated trees shed their leaves. Data after December, 1966, are not available.

Other records from Surinam all refer to specimens occurring in permanently inundated places. Whether the plants thrive with other aquatics (e.g., *Eichhornia crassipes, Salvinia auriculata*), or with marsh plants, or alone, there is always an ample supply of stagnant or even flowing water.

Reports of this species from Florida (St. John and St. John, 1935; Correll, 1938, p. 48; Darling, 1961) and from Panama (Woodson, 1946) seem to agree with the above observations (see also Benedict, 1909).

Ceratopteris deltoidea has been collected in Surinam four times. The first collection was from open water in a swamp in the Coronie District, northern Surinam, the second from the Paloemeu River, southern Surinam, the third from a former bed of Gran (also called Marowijne) Creek in the Brokopondo Lake area of central Surinam (van Donselaar, 1968), and the fourth from the Surinam River a little south of Brokopondo Lake. Because this species has been reported only from the southern United States, some of the Caribbean islands, and the coastal area of Demerara, Guyana (Benedict, 1909; De Vol, 1956), it seems likely that the Paloemeu River station in Southern Surinam is the southernmost yet known.

At the time that about ten floating specimens of *C. deltoidea* were found in the branch of Gran Creek, the expanding lake had reached the area. Therefore, it is not possible to present reliable data on the original habitat. Compared to *C. pteridoides*, the present species increased only moderately. Within a period of one and a half years it spread only a few kilometers from its original station.

According to Benedict (1909) and Safford (1912), *C. deltoidea* is found in ditches in Porto Rico and in Demerara. In Jamaica it was formerly found in "a clear flowing stream, a foot or two in depth . . . mostly in the quieter reaches near the shore, but sometimes well out in the current. The plant does not float except possibly in its juvenile stages of growth." (Benedict, 1909). Proctor recently collected the species floating along the River Mapi in Jamaica.

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A New Species of Cheilanthes from Mexico

IRVING W. KNOBLOCH AND DAVID B. LELLINGER

New, undescribed species of *Cheilanthes* are becoming increasingly rare in North America. The most recently described one, *C. carlotta-halliae* Wagner & Gilbert, was described more than ten years ago. New finds are not impossible, however. The new species described in this paper was discovered recently by the senior author and Dr. Paulino Rojas on a foray on the Chipinque Mesa in Nuevo Leon.

CHEILANTHES **chipinquensis,** *sp. nov.* *Plate 1*

Rhizomata compacta, multicipitia, ramis usque ad 5 mm longis, 2 mm diam., stipitibus fasciculatis; paleis linearibus, 3 mm longis, 0.3–0.4 mm latis, bicoloribus, vitta centrali nigra, crassa, nitida, marginibus fulvis, membranaceis, integris. Frondes 15–33 cm longae; laminis quam stipitibus 3–4-plo longioribus, teretibus, atropurpureis, villosis et paleaceis; villis semiadpressis, fulvis vel albescentibus; paleis linearibus, ca. 2 mm longis, 0.06 mm latis, 2–8 cellulis latis, patentibus, membranaceis, fulvis; indumento et colore rhachidis simili; laminis 10–24 cm longis, 3.5—7.5 cm latis, tripinnatis, anguste lanceolatis, basi paulo angustatis et truncatis vel interdum acutis, apice acutis, herbaceis; pinnis in 20–25 paribus alternis (interdum paribus basilibus oppositis), lanceato-oblongis, 15–30 mm longis, 5–10(12) mm latis, costis leviter sulcatis, villosis et paleaceis, paleis ca. 1 mm longis, 0.03 mm latis; pinnulis ascendentibus, oblongis integris, impari-

Holotype of Cheilanthes chipinquensis (Knobloch 1966B, MSC) pinnatis et segmento terminali maximo, costulis leviter sulcatis basin versus; segmentis obovatis, auriculato-oblongis vel oblongis, decurrentibus, marginibus 0.05–0.25 mm latis, reflexis, tenuiter membranaceis vel hyalinis, supra sparsissime sericeis, sublaevibus, subtus villosis, villis albescentibus. Sporangia subsessilia, subrotundata, annulo ex ca. 20 cellulis formato; sporis 64 per sporangium, 37–50 μ diam., globosis, laevibus, laesura brevi, impressa; numero chromosomatum $2n = 58$ ex cellulis apicis radicis a Knoblochio observato.

TYPE: Chipinque Mesa outside Monterrey, Nuevo Leon, Mexico, *Knobloch 1966B* (MSC; isotypes GH, MEXU, US).

Cheilanthes chipinquensis is most closely related to *C. tomentosa* Link. The two can scarcely be differentiated at a glance, but the characters in *Table I* distinguish them readily.

TABLE I. CHARACTERS DIFFERENTIATING C. CHIPINQUENSIS AND C. TOMENTOSA

Character	*C. chipinquensis*	*C. tomentosa*
Rhizome scale length	ca. 3 mm	ca. 5 mm
Frond length	to ca. 33 cm	to ca. 60 cm
Stipe scale length	ca. 2 mm	ca. 3 mm
Blade length	10—24 cm.	15—45 cm
Blade width	to 7.5 cm	to 9 cm
Blade division	3-pinnate below	3-pinnate-pinnatifid below
Pinna length	to ca. 30 mm	to ca. 35 mm
Pinna width	5—12 mm	5—15 mm
Pinna scale length	to ca. 1 mm	to ca. 2 mm
Basal pinnule segment width	to ca. 1 mm	to ca. 1.5 mm
Lamina indument above	sparsely sericeous or subglabrous	sericeous
Lamina indument below	villous	densely villous
Spores per sporangium	64	32
Diploid chromosome number	58	90

The new species is particularly well marked by the long terminal pinnule segments, which are several times longer than wide and which are much longer than those of *C. tomentosa*.

DEPT. OF BOTANY & PLANT PATHOLOGY, MICHIGAN STATE UNIVERSITY, EAST LANSING, MICHIGAN 48823 AND U. S. NATIONAL MUSEUM, WASHINGTON, D.C. 20560.

The Fern Collections in Some European Herbaria, II

C. V. MORTON

BOTANICAL MUSEUM AND GARDEN, BERLIN

A botanical garden was started in Berlin as early as 1646, but little is known about its early years. Very likely it was chiefly for the cultivation of medicinal plants, especially for the court. In 1679 it was relocated in Schöneberg, a suburb of Berlin, where it remained until early in the twentieth century. The garden remained little more than a park until the latter half of the eighteenth century when the director Johann Gottlieb Gleditsch (1714–1786) began introducing more plants of botanical interest. Gleditsch is remembered for his demonstration of bisexuality in higher plants. He produced fertile seeds from a female plant of the palm *Chamaerops humilis* in the botanical garden in Berlin by fertilizing it with the pollen from a male plant in the garden in Leipzig. This famous palm lived in the botanical garden up until the thirties of this century, and on its death was preserved for the Museum. Gleditsch is commemorated by the Honey-locust genus, *Gleditsia.*

Carl Ludwig Willdenow (1765–1812) was the nephew and student of Gleditsch. Willdenow was educated as a physician and received his M.D. from Halle in 1789, after which he managed his father's apothecary shop on the Unter den Linden in Berlin. He was appointed Professor of Natural History in the Berlin College of Medicine and Surgery in 1798. But he was really interested mostly in botany, and in 1801 was appointed Director of the Botanical Garden in Berlin, a post he retained until his death in 1812, at the relatively early age of 47. Willdenow was a productive man. He published his first major book, the "Florae Berolinensis Prodromus," when he was only 22. Among his about a hundred published works the most notable are the "Hortus Berolinensis," a work describing the plants of the botanical garden, and especially the fourth edition of Linnaeus' "Species Plantarum." The third edition (in two volumes with 1682 pages) appeared in

1764 during Linnaeus' lifetime. It was thus long out-of-date. Willdenow completely rewrote the work between 1797 and 1810 and amplified it greatly into five volumes containing 6499 pages. Willdenow's work was the last complete enumeration of the flowering plants and ferns of the world; it remained a useful reference work for many years, and is still of historical importance. Willdenow was especially interested in ferns, and treated them more fully than some other groups, or perhaps this is just an illustration of a general tendency among writers that I have noted—to elaborate as they go on. For instance, volume 1 of DeCandolle's "Prodromus" has very brief descriptions compared to those in all the later volumes. The early volumes of "Die Natürlichen Pflanzenfamilien" have brief generic descriptions compared to the later ones and especially to those in the second edition. The treatments in early volumes of "North American Flora" are short compared with the more recent issues. However that may be, Willdenow's treatment of the ferns is elaborate and fine for his day. Like all early works, it lacks keys or synopses.

Willdenow described several genera, but only two of them are now generally recognized—*Polybotrya* and *Taenitis*. *Pleopeltis* is sometimes recognized as distinct from *Polypodium* and *Lomaria* from *Blechnum*. The other genera of Willdenow were either homonyms—*Struthiopteris* (= *Matteuccia*), *Mertensia* (= *Gleichenia* subg. *Mertensia*), or synonyms, *Bernhardia* (= *Psilotum*). Willdenow did make one major blunder, the adoption of the illegitimate generic name *Aspidium* Swartz for one of the largest genera, although there were about six prior and legitimate available names. It may be assumed that this was on the circumscription, since *Aspidium* had been proposed for a large, composite genus, whereas the prior names had been applied only to one or a few species. Willdenow's influence was such that the name *Aspidium* was retained all through the nineteenth century, and even recently was proposed for conservation. However, aside from its original illegitimacy there is every reason to reject *Aspidium*, since it has been widely used in diverse senses, i.e., for the large genera *Dryopteris, Polystichum, Tectaria, Nephrolepis,* and perhaps others.

Willdenow assembled a large herbarium, mostly of specimens not of his own collecting. The ferns were obtained from many sources such as Swartz, Thunberg, Bredemeyer, Lamarck, Bory, Forster, Ventenat, Desfontaines, Langsdorff, Richard, Hoffmannsegg, Desvaux, Palisot, LaBillardière, and especially Humboldt and Bonpland. Of the 20,260 species in the Willdenow Herbarium over 3,000 were collected by Humboldt and Bonpland in their epoch-making journey to the Americas in 1799 to 1804. Alexander von Humboldt was Willdenow's most illustrious pupil, and his teacher instilled in him an interest in plant geography that he carried forward. Humboldt was himself never formally associated with the Botanical Garden, but he was a leader of German botany until he died at the advanced age of 90. Many of the new species described by Willdenow were manuscript names of Humboldt and Bonpland. These were referred to by Christensen in his "Index Filicum" as "H. B. Willd.," a usage maintained by Copeland, who justified it as "traditional"; however, the correct author citation is "Humb. & Bonpl. ex Willd." The other chief author of species described by Willdenow was Bory de St. Vincent, who sent him a full set of his collections from Réunion and Mauritius. Willdenow is commemorated by the genus *Willdenowia*, a South African genus of the Restionaceae and by the journal "Willdenowia" published by the Berlin Museum, a continuation of the former "Notizblatt."

The Botanical Museum in Berlin did not start during the lifetime of Willdenow. The Museum dates from six years later when Willdenow's successor as Director of the Botanical Garden, Heinrich Friedrich Link (1767–1851), persuaded King Friedrich Wilhelm III to purchase the Willdenow Herbarium for 36,000 marks in 1818, thus laying the foundation for the Museum. The Willdenow Herbarium was thus the basis of the general herbarium and has remained the single most valuable unit. It was kept separately from the other collections that Link had brought along to Berlin with him when he moved from Breslau. Strangely enough, the Willdenow Herbarium was not arranged by Willdenow himself; I was informed by Dr. D. E. Meyer, who is an authority

HENRI F^{c} LINK
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à Berlin.

H. F. LINK (1767-1851). PHOTO COURTESY OF HUNT BOTANICAL LIBRARY on the history of the Berlin Harbarium, that no sheets or almost no sheets bear annotations in the hand of Willdenow. In 1819, the new Director Link appointed Diederich Franz Leonhard von Schlechtendal (1794–1866), then a young man of 25, as the first curator. Schlechtendal undertook to arrange the Willdenow Herbarium according to Willdenow's own edition of the "Species Plantarum," and his arrangement persists to this day. Through the courtesy of Dr. Meyer and of Dr. Rolla M. Tryon, Jr., the National Herbarium has a photographic copy of the fern part of the Catalog of the Willdenow Herbarium. Naturally, these valuable specimens are not available for loans. I understand that there is some prospect that all of the specimens may be photographed and the photographs made available for sale. There is some problem about this, because very often the names and data for the specimens are written on the back of the herbarium sheet, and often rather illegibly too, and so to be fully useful this data ought to be available along with the photographs. As is true with most old herbaria (and with new ones too) the specimens vary in quality, some being poor fragments and some fine complete specimens. Among the collections to be mentioned especially are those of Swartz. Swartz sent a rather full set of his Jamaican collections (the ferns at least) to Willdenow. In some cases he may even have sent all the material that he had, and so the Willdenow Herbarium is a valuable supplement to the Swartz Herbarium in Stockholm for identifying Swartz' species.

The Directors of the Botanical Garden in Berlin have been long in tenure in their offices—only five in the 130 years between 1815 and 1945, and they were all outstanding botanists—Link, Braun, Eichler, Engler, and Diels. Although Link was a contemporary of Willdenow, being born in 1767 only two years after Willdenow, he lived 38 years longer and was still Director at the age of 88 when he died in 1851. Link was an old-time general scientist, being interested in physics, chemistry, mineralogy, zoology, pharmacy, natural philosophy, and of course particularly in botany, in which he published especially on anatomy, but also on systematics. His chief contribution is the book "Filicum Species in Horto Regio

Botanico Berolinensi Cultae" (1841), in which he lists the known cultivated ferns. Link had a keen eye for genera, and described over a hundred, including among the ferns a number of universally recognized genera that had been passed over by previous workers on the genera of ferns like Bernhardi, Swartz, Kaulfuss, Gaudichaud, and Desvaux, such as *Pellaea, Pityrogramma, Camptosorus, Actiniopteris,* and *Anogramma.* Some of his other proposed genera are sometimes adopted, like *Microsorium, Craspedaria, Cyclosorus,* and *Acropteris.* Link himself collected specimens in the gardens and greenhouses and the labels in his handwriting clearly establish his types. A number of these cultivated specimens were distributed to other institutions; all that I have seen are correctly named, and so these may be truly considered authentic for their species even though they can not be proved to be isotypes. Very likely Link went back to the same plant or plants and collected additional specimens when they could be made without injury to the plants; these specimens would qualify as "clonotypes," i.e., specimens collected later from the type plant or plants, and thus not truly types but still authentic. Link was not the only one to do this by any means. Link was also interested in fungi. Perhaps his most celebrated accomplishment was the description of a new genus of molds that he called *Penicillium* (the name adapted from the Latin name for a pencil, in allusion to the shape of the filaments), a genus later to become famous as the source of the drug penicillin.

A year after Schlechtendal was appointed as the first curator a second curator, Adelbert von Chamisso (1781–1838), was appointed. Just previously Chamisso had travelled around the world on the "Rurik." Chamisso did not work on his own fern collections, which were entrusted to Kaulfuss, but he did work with Schlechtendal on the plants of Mexico collected by Schiede and Deppe. Schlechtendal remained in Berlin only 15 years, until 1833, when he went to Halle as Professor. There he continued to edit and publish the botanical journal "Linnaea" for the rest of his life, until 1866. Chamisso remained as curator in Berlin until his death in 1838.

The outstanding botanist in Berlin during the first half of the nineteenth century was Carl Sigismund Kunth (1788–1850), who was a student of Willdenow and later Vice-Director of the Botanical Garden. Kunth undertook the publication of Humboldt and Bonpland's "Nova Genera et Species Plantarum," which he issued in seven volumes between 1816 and 1825, both in a quarto and simultaneously in a folio edition. It has been thought by some that this work was written wholly by Kunth and was attributed jointly with Humboldt and Bonpland only out of courtesy, but there is no indication of this in the text, and I have been assured that the original manuscript exists in the library of the Jardin des Plantes, Paris, showing that Humboldt and Bonpland did indeed write a part of the text. Kunth is chiefly known for his "Enumeratio Plantarum" issued in five volumes between 1833 and 1850; this is devoted altogether to the monocotyledons, and especially to the grasses and sedges.

Following the death of Link and Kunth about the same time, the Directorship was entrusted to Alexander Braun (1805-1877), a talented botanist who was interested chiefly in morphology, being a pioneer in such subjects as polyembryony, alternation of generations, parthenogenesis, and teratology. He was an authority on the Characeae (algae) and pteridologists know him as *the* authority on *Marsilea,* although he worked as well on other ferns and fern allies, such as *Pilularia, Isoëtes,* and *Equisetum.* Braun's work on *Marsilea* has never been really reviewed or checked, a task that urgently needs doing.

Following Chamisso the curator was Johann Friedrich Klotzsch (1805–1860), who worked on many groups of plants but who was probably best known as a fern student. He published many species of ferns from tropical South America. Closely associated with him and with Link was the Head-Gardener Friedrich Otto (1782–1856), himself an authority on many plants, especially cultivated ones. Among the assistants working under Braun were Johannes Hanstein (1822–1880), another pioneer student of plant morphology but known today chiefly as the monographer of the Gesneriaceae, August Garcke (1819–1904), famous for his "Illustrierte Flora von Deutschland," published first in 1849, with at least 22 editions up until 1922 and perhaps later, and especially the famous Paul Ascherson (1834–1913), who was truly phenomenal in his productivity, producing over 1500 published works in his 79 years. He is, of course, best known for the "Synopsis der mitteleuropäischen Flora," written in collaboration with Paul Graebner (1871–1933), which was published between 1896 and 1938. This is a standard reference work on the flora of central Europe, but it must be confessed that the names used leave much to be desired, for the authors had their own ideas about rules of nomenclature. They were also prone to use many group names, the exact rank of which is a bit uncertain.

After the death of Braun, August Wilhelm Eichler (1839–1887) became Director. He was Director for only 11 years and perhaps did not accomplish quite so much as the others. His most famous work is the "Bluthendiagramme" (Flower Diagrams), a book of illustrations in which the arrangement of the sepals, petals, stamens, and pistils is diagrammed carefully for most of the genera of flowering plants. This unique book has never been superseded and is still as useful as it ever was. Eichler also published a "Syllabus der Pflanzenfamilien" in 1876 which was the model for the later publications of the same title and in which the system of plant families associated with Engler is first set forth.

Adolf Engler (1844–1930) was a close associate of Eichler and followed him as Director in 1889. Engler was a hard worker himself and talented, but his chief accomplishment was as an administrator and as an organizer and coordinator of several vast projects—"Die Natürlichen Pflanzenfamilien," (begun with K. Prantl), a complete enumeration and description of all the plant families and genera, including the cryptogams, "Das Pflanzenreich," a long series of monographs of families (some of them such as Araceae and Saxifragaceae done by Engler himself), and "Die Vegetation der Erde" (with O. Drude). In order to produce these works Engler employed many German taxonomists working between 1889 and 1921. The Berlin museum was a scene of great activity, even to some extent during the war years of 1914–1918. The list of contributors to "Das Pflanzenreich" includes some of the best German taxonomists, such as Gilg, Schumann, Radlkofer, Niedenzu, Mez, Pax, O. E. Schulz, and many others, as well as a few non-Germans like Cogniaux, Rendle, Skottsberg, Macfarlane, and others. In addition to the works mentioned, Engler also put out the "Botanisches Jahrbuch," one of the most important periodicals on taxonomic botany. Engler was instrumental in getting the garden and museum moved from Schöneberg to Dahlem, a suburb on the south side of Berlin.

Other important botanists connected with Berlin are too numerous to mention. The Director from 1921 to 1945 was Ludwig Diels (1874–1945), also a pteridologist and the author of most of the fern part of "Die Natürlichen Pflanzenfamilien." Ignatius Urban (1848–1931), the foremost authority on the plants of the West Indies, was still actively at work at the age of 83 in studying the then recent collections of Ekman from Haiti. Other famous staff members in Berlin included Georg Schweinfurth, Karl Schumann, Georg Hieronymus, Gustav Lindau, Ernst Gilg, Johannes Mildbraed, Otto Warburg, Paul Graebner, Ernest Harms, and Maximilian Burret.

And now I come to a sad event, the greatest catastrophe that botany has ever suffered. On the night of March 2, 1943, the Botanical Museum suffered a direct hit in a bombing raid, and nine-tenths of the herbarium, estimated at 4,000,000 specimens, was destroyed in the subsequent fire. Doubtless the bombing was not intentional, since the Museum was not a military target, but such accidents are to be expected in bombing conducted at night under wartime conditions. Whether the Director Diels felt that the Museum was safe or whether he would have liked to evacuate it from Berlin but was not permitted to is perhaps not known. There are some botanists yet living who were present at the time, but they may not have been in Diels' confidence. At any rate, after the bombing the remaining specimens, numbering about 400,000, were removed to a rural spot in Thuringia.

Fern students can be thankful that by some miracle the fern herbarium survived the fire intact, the only major group to do so, and it now illustrates the wealth that was in the general herbarium. The fern collection is perhaps the largest in the world, numbering possibly 300,000 specimens or more, and also perhaps the single most valuable one, due to the great activity of German botanists generally in systematic work and especially to the fact that the ferns seem to have been favorites of the staff. The fern works of Willdenow, Link, Braun, and Diels have already been mentioned. The two most eminent German pteridologists of the nineteenth century were Georg Mettenius and Gustav Kunze, both of whom worked in Leipzig. The Kunze Herbarium was completely destroyed during world War II, but the herbarium of Mettenius, had been acquired previously by Berlin. It includes not only Mettenius' own types but also many specimens named by Kunze, and there are other isotypes and syntypes of Kunze in Berlin; for this reason most of Kunze's species can be lectotypified on material in Berlin. Unfortunately, the Mexican collections of Leibold that Kunze described do not usually have duplicates in Berlin and there are few duplicates anywhere, and so it is more of a problem to locate possible lectotypes of these.

In contrast to the few Directors prior to World War II, since 1945 there has been a rapid succession of Directors in Berlin—R. Pilger, J. Mattfeld, E. Werdermann (under his direction the herbarium was brought back to Berlin), H. Melchior, W. Domke, and the present incumbent T. Eckardt—thus six in about 20 years. Under these Directors the Botanical Garden, which was in sad shape after the war due to neglect and bombing damage, has been restored until it is now again one of the finest in the world. The greenhouses have been rebuilt and enlarged and are well stocked, and the gardens are full of interesting and well-grown plants.

Berlin was fortunate in having a fern curator for many years as talented and industrious as Georg Hieronymus (1846–1921), during his lifetime *the* great authority on ferns. He was especially noted as a specialist on *Selaginella*, having written the account for "Die Natürlichen Pflanzenfamilien," an account so detailed that it almost constitutes a monograph; he subsequently wrote a long series of papers on the genus and on ***Pteris***, *Asplenium*, *Coniogramme*, and others. His associate at Berlin, Guido Georg Wilhelm Brause (1847–1922) also published many papers on ferns in the Berlin Herbarium. It may be noticed that most of the men who have been mentioned lived into their seventies or eighties, and not only lived but remained productive, thus showing that conditions in Berlin must be especially salubrious for botanists.

My visit was in 1964, when I was cordially received by Dr. Domke, and by Dr. D. E. Meyer, who is at present in charge of the fern herbarium. The collection is so vast that I could go through only a few genera in which I am especially interested—*Asplenium*, *Blechnum*, and *Gleichenia*. In spite of being so large the herbarium is eminently usable, due to Hieronymus, who evidently spent years in arranging the herbarium in its present form, which is strictly systematic. The species are not arranged alphabetically (except perhaps in some of the smallest genera), but according to Hieronymus' own ideas, and the herbarium itself therefore represents a kind of unpublished system of ferns. It is therefore absolutely necessary to use the indices to the species prepared by Hieronymus. (It is to be hoped that these indices have been photographed or otherwise duplicated, so that if any of them should ever be lost or misplaced they can be easily replaced.) A unique feature of the arrangement is that when species were placed in synonymy the specimens were not integrated but rather kept in their own folder at the end of the other material. Thus although *Aspidium violascens* Link was considered by Hieronymus as a synonym of *Dryopteris dentata*, the specimens that were in the original cover *violascens* are still all together, and consequently one can readily find the material that Link, Klotzsch, or other botanists may have referred to this species. For this reason the herbarium rightly has a rule that no specimens may be transferred from one cover to another even though they may be reidentified. (Of course, all rules must have their exceptions, and specimens obviously misfiled ought to be moved to their proper places, but these are few compared to most herbaria.) The newly described species since the time of Hieronymus are kept in a separate series arranged alphabetically at the end of their genera.

From all appearances the fern collections in Berlin have not been worked over much since the time of Hieronymus and Brause; at least there are few annotations by later botanists. It would be impossible to list here all the important collections. Most of the important ones are mentioned by Urban in his exhaustive work "Geschichte des Königlichen Botanischen Museums zu Berlin-Dahlem (1815–1913) nebst Aufzählung seiner Sammlungen" (Dresden, 1916), which should be consulted for further information on the history of the Berlin museum. Among the most historically important collections is the Kurt Sprengel Herbarium (at least as to the ferns). In addition to the types of Willdenow, Link, Braun, Brause, Hieronymus, Diels, Klotzsch, Kunze, Mettenius, and Schlechtendal and Chamisso, the herbarium also contains the types of Krug, Kuhn, Prantl, Schumann and Lauterbach, Reimers, Hillebrand, and Goldmann (the Meyen collections), and some authentic specimens of Forsskal, Forster, Kaulfuss, Langsdorff and Fischer, Presl, and many others.

Most of the above information has been taken from the publication "150 Jahre Botanisches Museum Berlin (1815–1965)" by T. Eckardt (Willdenowia **4**: 151–182. 1966), a copy of which was kindly sent to me by Dr. Eckardt.

(*To be continued*)

The Stelar Anatomy of Diplazium latifolium Moore

S. S. BIR[1]

The anatomy of some species of *Diplazium* Swartz has been studied in detail by Ogura (1921, 1927, 1938) and by Tardieu-Blot (1932). However, until now the anatomy of the Himalayan members of the genus has not been investigated. The stelar structure of *Diplazium latifolium* Moore[2] is particularly interesting, and is presented briefly here.

Specimens of *D. latifolium* are abundant near water at 900–2700 m altitude in the central and eastern Himalayas. Material for this study was collected from Lebong forest, Darjeeling, at an altitude of 1500 m. The fronds are about one meter long. The stipes are 30 to 40 cm long, atropurpureous at base and stramineous toward the apex, and are smooth. The laminae are herbaceous, bipinnate to tripinnatifid, and are 60 to 90 cm long and 20 to 45 cm broad. The pinnae and pinnules of the Himalayan material are variable in size and shape, and can be sorted easily into four forms, but certainly these cannot be recognized as varieties. This study is based on specimens of the typical form.

The rhizome is large, suberect or ascending, stout and woody, with 3 or 4 rows of densely tufted stipes. The stelar structure was studied by extracting intact steles from the rhizome after mild maceration in modified Schultz's fluid (1% potassium chlorate in 50% nitric acid). Portions of the rhizome were macerated for about 12 to 18 hours. Then all cortical and ground tissues were removed by dissection in water, exposing the vascular portions, which were preserved in 75% alcohol.

The stelar structure in the rhizome and stipe is unusual compared to the allied species *Diplazium polypodioides* Blume, *D. asperum* Blume, and *D. maximum* (Don) C. Chr. The rhizome is about 2.5

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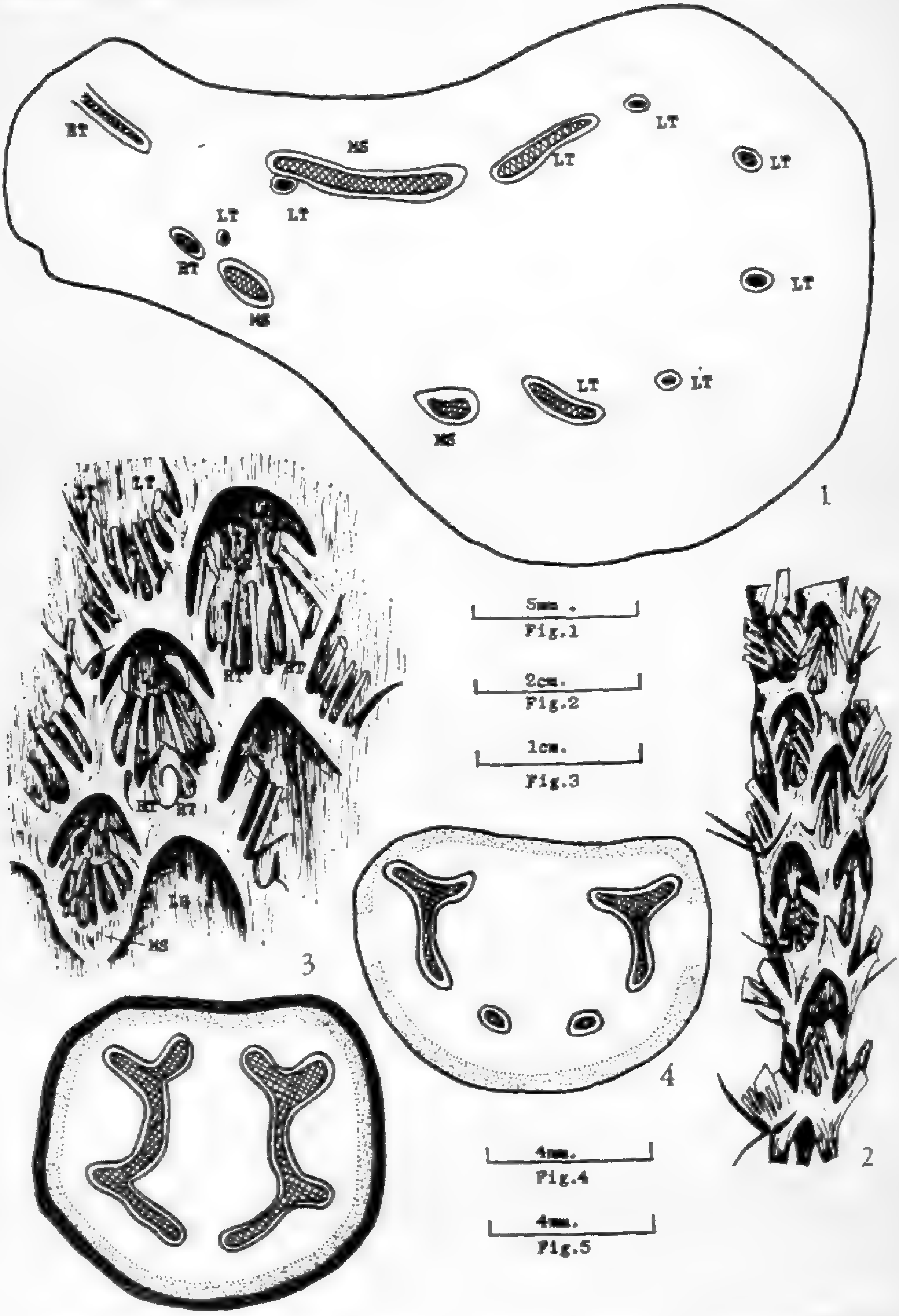
[1] My sincerest thanks to Prof. P. N. Mehra, Chandigarh, India, for his encouragement and inspiration and to Mr. C. V. Morton for his helpful criticism.

[2] *Diplazium latifolium* Moore is a legitimate new name based on *Asplenium latifolium* Don (1825), *non* Bory (1803); *D. indicum* Nair (1968) is superfluous.



Stelar Anatomy of Diplazium latifolium. Fig. 1. Cross section of rhizome. Fig. 2. Stele extracted from rhizome. Fig. 3. Same, showing details of structure. Fig. 4. Cross section of petiole. Fig. 5. Same, upper region. The abbreviations are: LG = leaf gap, LT = leaf trace, MS = meristele, PN = pneumatophore, and RT = root trace.

cm in diameter, about the same as in *D. polypodioides*. There are three to five meristeles. The leaf gap opens following the (usual) detachment of a single, basal root trace. Above this point, just at the base of the leaf gap, three to five or more root traces arise from the outer face of the meristeles. At the point where these pass into the cortex, up to five small, accessory, leaf trace strands depart from the inner face of the meristeles, mostly opposite the point where the root traces depart from the outer meristele faces. Two large leaf traces abstrict from the sides of the meristeles just below the middle of the leaf gap, which is small. There are thus four to seven leaf traces, two large and two to five small ones. *Figure 1* shows a transection of the rhizome with three meristeles (MS). Two are oval and the third appears elongate due to the closure of the leaf gap. A leaf base at the right side has two large and four small, accessory leaf trace strands (LT). At the left is a basal root trace passing out into the root, with one additional root trace departing from the outer face of the meristele and two small leaf trace strands in the process of detachment from the inner faces of the meristeles. The entire structure is shown clearly in the extracted stelar skeleton (*Figs. 2* and *3*).

In their further course into the petiole the large leaf trace strands develop ridges and grooves and become somewhat W-shaped. The smaller, accessory leaf trace strands may anastomose with one another after entering the petiole, and finally fuse with the larger ones. In the lower portion of the petiole there may be two large, ridged and two small, oval leaf trace strands (*Fig. 4*), but about 15 to 20 cm above the leaf base there are only two W-shaped strands (*Fig. 5*). The keels of the two large leaf strands persist for some distance into the rachis, even when the two strands fuse to form a single U-shaped strand, but farther up they disappear. The pinna trace is extramarginal in origin. The keels or ridges present on the leaf strand in the petiole not only give mechanical support to the petiole, which bears a large lamina, but primarily increase the area of conduction. Meristele structure in the rhizome and leaf strands is the usual type for *Diplazium*, *Athyrium*, *Diplaziopsis*, etc. (Tardieu-Blot, 1932; Bir, 1965). In the xylem region the tracheids are intermixed with xylem parenchyma.

The stelar structure of the rhizome and petiole of *Diplazium latifolium* f. *latifolium* is more complex than that reported for other species of *Diplazium,* and contrasts with *D. maximum* (Don) C. Chr., a species with which it has often been confused. *Diplazium maximum* has a less complex rhizome, lacks accessory leaf trace strands, and has root traces that do not depart opposite the leaf trace strands. The four to seven leaf trace strands in the leaf bases of *D. latifolium* also contrast with the usual two strands that characterize *D. maximum.* This is an important diagnostic feature which supports the taxonomic separation of the two species.

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DEPARTMENT OF BOTANY, PUNJABI UNIVERSITY, PATIALA, INDIA.

Notes and News

THE SECRETARY HAS RECEIVED the following letter from our newly-elected honorary member:

50 Gloucester Court,
Kew Road,
Richmond, Surrey,
22 December 1968

Dear Mrs. Atkinson,

Thank you very much for your letter of 14 December, written on behalf of the American Fern Society, telling me of my election to Honorary Membership of the Society.

I greatly appreciate this honour, and would like to express my thanks to the Society. The Society has done much, over many years, to promote an active interest in ferns, not only in America but in other parts of the world, and I send good wishes for its continued progress and prosperity.

The Society could not continue to exist without a great deal of voluntary work on the part of its officers. For a number of years I have felt grateful to the Secretaries, Editors and other officers of the Society for the work they have done, and assure them of my continued appreciation of their services.

Yours sincerely,
R. E. Holttum

THE FERN SOCIETY will hold an informal luncheon at Tuesday noon on August 26 at the Sherwood Motor Inn, which is located at N.E. 45th Street and the Freeway in Seattle. The luncheon is being held during the XI International Botanical Congress, but is *not* restricted to Congress members. All Fern Society members and friends of the Society who wish to attend should make their reservations directly with Mr. Neill D. Hall, 1225 Northeast 95th Street, Seattle, Washington 98115.

FERNS WANTED.—I would like to learn of sources for *Cardiomanes reniforme* and for *Pellaea* species other than *P. atropurpurea*.—JOHN A. KNOUSE, *1338 Sleepy Hollow Road, York, Pa. 17403.*

Recent Fern Literature

DIE FARNE DER INSEL TENERIFE, by Gerhard Benl, Nova Hedwigia **14:** 69–105. 1967.—Tenerife is the largest of the Canary Islands. Its ferns have been long known, but most lists use incorrect names. Dr. Benl has tried to use up-to-date names and has also provided a usable key and interesting comments. Altogether 40 species and varieties are treated. Persons familiar with the ferns of the United States would recognize many of the Tenerife ferns, which include such species as *Adiantum capillus-veneris, Pteris vittata* (very similar to *P. longifolia*), *Pteridium aquilinum* subsp. *capense, Hymenophyllum tunbridgense, Trichomanes speciosum* (very like *boschianum*), *Cyclosorus dentatus, Asplenium trichomanes, A. septentrionale, Athyrium filix-femina, Cystopteris diaphana* (similar to *C. fragilis*), *Polystichum setiferum* (like *P. dudleyi*), *Dryopteris oligodonta* (similar to *D. filix-mas*), *D. dilatata, Blechnum spicant, Woodwardia radicans* (similar to *W. fimbriata*), *Polypodium australe* (similar to *P. vulgare*), several *Cheilanthes* similar to American species, and *Ophioglossum lusitanicum.* Other plants well known in Europe but not found in the United States are *Anogramma leptophylla, Asplenium marinum, A. hemionitis, A. onopteris, A. adiantum-nigrum,* and *Ceterach aureum* (similar to *C. officinarum*). Unquestionably the most peculiar and distinctive plant of the island is *Adiantum reniforme,* an *Adiantum* with a simple, round blade, which is endemic in the Canary Islands and Madeira. Another famous plant is the endemic *Davallia canariensis,* beloved for its use in hanging baskets throughout the world. The rarest fern is undoubtedly the endemic *Cheilanthes guanchica* Bolle, known from only a few collections from Tenerife. The only taxonomic decision that I would question (other than the excessive splitting of the families) is the adoption of the name *Pteris serrulata* Forssk. for the species commonly known as *P. arguta* Ait. This is an error on which I shall publish a note elsewhere.—C.V.M.

American Fern Society

Report of the President for 1968

I wish to take this opportunity to wish you all a happy New Year, and especially to welcome all of our new members.

One of the most important events of the past year was the very enjoyable foray conducted in southern Ohio by Drs. Hauke and Wagner. A report of our "finds" on these trips is presented in another section by Dr. Montgomery. (Next year, we will not have a field trip but I hope that you will follow the forthcoming announcements on the XI International Botanical Congress in Seattle and plan on going on some of the botanical trips in the beautiful northwest.) Drs. Frederick and Decker deserve our special thanks for their aid with the annual meeting, field trip, and luncheon. Drs. Mickel, Wagner, and others organized a very fine symposium on pteridophytes as they related to the forthcoming "Flora of North America." The six papers presented were very thought provoking indeed.

It is not possible to mention all the interesting papers published this past year on ferns and their allies. A few items that come to mind are: Steeves, Sussex, and others showed how leaf primordia of the Cinnamon Fern can be made to grow into small but complete plants; Wardlaw, Cutter, and others, working on the stem apex of ferns, showed that there is an inhibitive, physiological zone around each future leaf; the bracken fern has been found to contain a hormone (ecdysterone) that interferes with the molting of certain insects, and thus we may have another avenue of approach to the biological control of insects; *Polypodium decumanum* growing in Honduras is *said* to contain tumor-arresting properties (I have no other information); many researchers are working on the proper wave length of light for the initiation of two-dimensional growth in fern prothallia, on the relationships between proteins and ribose nucleic acid in prothallia, and on apogamous gametophytes. Farrar and Wagner discovered that, among other things, *Trichomanes holopterum* gametophytes are more numerous than the sporophytes. Lellinger and myself have found another example of a disjunct range of ferns: *Cheilanthes castanea,* a fern of the southwestern United States, has been found in Virginia and West Virginia. Rolla M. Tryon, Jr., C. V. Morton, Dean Whittier, Thomas Pray, Dr. Alice Tryon, and others, continued their fine work during the past year.

During 1969 we have many plans for the Society. One idea we have is to encourage local chapters of the parent organization. Frankly, we would like to see a more vigorous membership growth and local chapters may be the answer. The *modus operandi* has not been worked out as yet but we would like to hear from volunteers who might have the time to set up local groups. Several of our members are engaged in drawing up a new membership list. Please keep Dr. Henry informed of any address changes.

Two other projects which, if completed, would help our members are the preparation of a list of those fern genera which have already been monographed and a comparison of fern classification systems, down to the level of genera. It is to be hoped that some person or persons will become interested in these areas.

Drs. Faust, Foster, and Lellinger are going to develop an index to our JOURNAL, from the 26th volume on. When finished, the index should be of great value to each and every one of us. Drs. Wagner, Lellinger, and your President will soon start on the organization and writing of a booklet on ferns. This will cover many areas and will be a good introduction to the pteridophytes.

May I respectfully point out that the publication of the Index and the booklet on ferns will together cost more than four thousand dollars. Money may be the root of all evil to some, but to the American Fern Society it would be, *if* we had some, a means of getting the above two projects out of the talking stage. I am calling upon all members to remember the Society financially in whatever manner is most suitable to them. We would appreciate such an effort.

Respectfully submitted,

IRVING W. KNOBLOCH, *President*

Report of the Secretary for 1968

The American Fern Society at the close of 1968 has 633 members from all states of the Union excepting the Dakotas, Montana, New Mexico, and Wyoming, and from 28 countries abroad.

Regretfully I report the death of seven members, four of them of long standing: Miss Grace Zelley, a member for 26 years; Mr. E. P. Killip, a member since 1916; Miss Alma G. Stokey for 19 years and an Honorary Member since 1953; Mr. Austin T. Foster, a member for 17 years; Mr. Forest Green and Mrs. Richard Dunlop who joined in 1966 and Mrs. Noah Kassman in 1967.

The annual meeting of the Society held September 3 and 4 with the American Institute of Biological Sciences on the campus of Ohio State University was preceded by a luncheon for forty people, President Irving Knobloch presiding. President Knobloch introduced Dr. Jane Decker who presided at the first afternoon session attended by sixty-six persons. The titles of papers read are, in order of presentation: "Distribution of the ferns of Mississippi," by Thomas M. Pullen; "New fern records in Illinois," by Robert H. Mohlenbrock; "A new genus of polypodioid ferns from Central America," by A. Murray Evans; "The phylogenetic position of *Toppingia*, a genus of apparently thelypteroid alliance," by Alan R. Smith, read by John T. Mickel; "A new natural hybrid in the Appalachian *Asplenium* complex and its taxonomic significance," by W. H. Wagner and Florence S. Wagner, read by Florence S. Wagner; "Interspecific relationships of the bog club mosses, *Lycopodium inundatum* complex, of North America," by Susan Stephenson; "An investigation of angle-meristem development in excised stem segments of *Selaginella martensii* Spring," by Terry R. Webster; "The gametophyte of '*Dryopteris*' *keraudreniana*," by Lenette R. Atkinson; "Gametophytic maturation in sexual and apogamous ferns," by Dean P. Whittier; "Vegetative reproduction in *Trichomanes*—associated with spore abortion?," by Donald R. Farrar; and "Proposals toward an automated index of pteridophyte names and type specimens," by David B. Lellinger.

On Wednesday afternoon, September 4, a symposium "Pteridophytes in the Flora of North America," arranged by the American

Fern Society and co-sponsored by the American Institute of Biological Sciences, American Society of Plant Taxonomists, and Systematic Section, Botanical Society of America, was attended by 140 persons. Dr. John T. Mickel presided and introduced the symposium with a "Critique of pteridophytes and Flora Europaea and Flora SSSR." Four papers were presented: "Problematic groups in the 'fern allies' and the treatment of subspecific categories," by Richard L. Hauke; "Problems of apomixis and the treatment of agamic complexes," by A. Murray Evans; "The role and taxonomic treatment of hybrids in the Flora North America," by Warren H. Wagner, Jr.; "Taxonomic problems in the geography of North American ferns," by Rolla M. Tryon. A summation of the symposium and future activities of the Flora North America project by Peter H. Raven closed the program.

At a meeting of Council it was voted to reprint back issues nearing exhaustion. A new membership list and an index of the JOURNAL (Vols. 26–60) are being prepared.

The Society is honored by Dr. R. E. Holttum's acceptance of Honorary Membership (See Notes and News).

As I leave office I wish to thank all who have helped in reducing the secretarial load. I am especially grateful to Dr. D. G. Huttleston, my predecessor, for his early advice and for continued willing aid. The Society is to be commended on its excellent choice of a new secretary, Dr. A. Murray Evans.

Respectfully submitted, LENETTE R. ATKINSON, *Secretary*

Report of the Treasurer for 1968

In 1968 the receipts were $10,742.44, an amount much larger than that received during 1967. This amount was greatly increased by a $3,000 bequest from the Estate of Edith Scamman, by $565 contributed by the members for the International Botanical Congress, and by one Life Membership of $80. Also the receipts from regular sources were increased by $1,800 over those of 1967.

Receipts for the sale of back issues of JOURNAL exceeded those of 1967 by $823.33. Royalties from Dr. Wherry's books exceeded those of 1967 by $55.44.

Advances from dues were $120 and from subscribers $815.40. The former is $7 less and the latter $11 less than last year.

We obtained 25 new subscribers during 1968 and lost six, making a gain of nineteen.

Considering all of this, I believe that the Society is in good financial condition at the present time.

Receipts

Cash on hand, January 1968			$2,835.32
Membership dues			
Renewals	$1,863.50		
Sustaining	112.00		
New	276.30		
Advance	120.00		
Arrears	36.00		
		$2,407.80	
Subscriptions			
Current	$362.60		
Advances—1969	764.40		
Advances—beyond 1969	51.00		
Arrears	12.10		
		$1,190.10	
Life memberships		80.00	
Sale of back issues		2,265.82	
Sale of reprints		474.17	
Royalties (Wherry's Books)		493.93	
Gifts		5.72	
Memorials		10.00	
Page and plate charges		210.00	
Advertising in Journal		33.90	
Spore Exchange		0.00	
Miscellaneous		6.00	
Contribution to Intern. Bot. Congress		565.00	
Bequest from Scamman Estate		3,000.00	
Total receipts			$10,742.44
Total			$13,577.76

Disbursements

American Fern Journal			
Vol. 57, No. 4	$1,013.53		
Vol. 58, No. 1	1,002.68		
Vol. 58, No. 2	1,006.77		
Vol. 58, No. 3	1,059.02		
		$4,082.00	
Reprints and postage		520.86	
Envelopes for mailing Journal		89.00	
Printing stationery, envelopes, bills, etc.		149.63	
Printing 3 sets of membership cards		29.49	
Treasurer's expenses		115.00	
Secretary's expenses		134.03	
Editor's expenses		30.89	
Foray expenses		57.06	
Shipping and handling back issues for 1967		44.46	
Shipping and handling back issues for 1968		29.69	
Book Exhibit		19.50	
Advertisement of Soc. in L.A. Fern Publ.		10.00	
AIBS dues		400.00	
AAAS dues		10.00	
Contribution to Intern. Bot. Congress		900.00	
Miscellaneous		54.00	
Total disbursements			$6,675.61
Cash on hand, January 1, 1969			$6,902.15

Statement, December 31, 1968

Assets

Cash in Union National Bank	$6,902.15	
Cash in Green Point Savings Bank		
Bissell Herbarium Fund	1,042.27	
Life Membership Fund	1,607.13	
Una F. Weatherby Fund	4,342.47	
Accounts receivable	328.25	
Inventory, Journal	7,069.60	
Library	396.00	
Total		$21,687.87

Liabilities		
Advance dues	$120.00	
Advance subscriptions	815.40	
Fund Balances		
Bissell Herbarium Fund	1,042.27	
Life Membership Fund	1,607.13	
Una F. Weatherby Fund	4,342.47	
General Fund	13,760.60	
Total		$21,687.87

Respectfully submitted,

LEROY K. HENRY, *Treasurer*

Report of the Auditing Committee

We hereby certify that we have seen the books and accounts of Dr. LeRoy K. Henry, Treasurer of the American Fern Society, Inc., and have obtained confirmation of the correctness of the Society's balance on hand as set forth in detail in the accompanying report of the Treasurer.

DOROTHY L. PEARTH, *Auditor*

Report of the Judge of Elections

The results of balloting for officers of the American Fern Society are as follows:

For President:	
Irving W. Knobloch	292
For Vice-President:	
Warren H. Wagner, Jr.	290
For Secretary:	
A. Murray Evans	287

I therefore declare the following candidates elected to office: Irving W. Knobloch, President; Warren H. Wagner, Jr., Vice-President; A. Murray Evans, Secretary.

The amendment to the Constitution was voted on as follows: Under Article III change Section 2 to increase admission fee and annual dues to $5.00; change Section 3 to increase sustaining membership to $10.00; change Section 4 to increase life membership to $100.00.

For: 259 Against: 37

I therefore declare the amendments to the Constitution of the American Fern Society approved by the membership and now in force.

It is also my privilege to declare Dr. Richard Eric Holttum elected to Honorary Membership in the American Fern Society.

Respectfully submitted,

DEAN P. WHITTIER, *Judge of Elections*

Report of the Fern Spore Exchange

The Fern Spore Exchange has made significant growth, in many ways, during the year 1968. More species have been received and disbursed than in previous years. Many new requests for participation in the Exchange have come from universities in distant countries.

A complete new spore list will be available early in 1969. This list will cover over three hundred species and varieties of ferns collected in 1967 and 1968. The contributors were evenly distributed between the United States and the rest of the world. Institutions outside the United States have contributed many rare ferns to the Exchange.

I wish to pay tribute to all the faithful members who have consistently contributed fresh spores to the Exchange year after year. The continuing support of all the members of the Society will insure the success of the Exchange.

Please collect and send in fresh spores or fertile fronds before October of each year. All species are desired, no matter how common.

Respectfully submitted,

NEILL D. HALL, *Director of the Spore Exchange*

Report of the 1968 Fern Foray

The 1968 Foray was held in the Chillicothe area of southern Ohio. The group assembled on Saturday, August 31, at the Chillicothe Holiday Inn. We were greeted by a large sign saying "Welcome Fern Society." The evening was spent renewing acquaintances and finding out the latest news. Sunday morning the group assembled in cars and set out for a limestone quarry near Peebles. The 1968 foray was aimed at finding unusual species and investigating groups in which there is hybridization. Thus, although many of the species in the area were familiar to many of us from the East, we saw some really unusual things.

At Peebles we scrambled along a stream, finding several limestone ferns such as *Pellaea glabella* and *Asplenium rhizophyllum.* We did not find the rare hybrid *Asplenium* × *inexpectatum* (*A. rhizophyllum* × *ruta-muraria*), for which this is the type locality.

From Peebles we traveled to McArthur, stopping first for lunch at a roadside park near Beaver, where *Asplenium pinnatifidum* grew on rocks. Near McArthur we found *Lygodium palmatum* growing in abundance in a thicket with a large number of other species of wet woods. Our last stop for the day was near Jackson. Here, growing on the dark underside of an overhanging ledge we saw the interesting Appalachian gametophyte of *Vittaria. Lycopodium porophilum* grew along the ledges. *Asplenium montanum* and *A. pinnatifidum* were fairly common along the steeper parts, and several plants of their hybrid *A.* × *trudellii* were found scattered with the parents. We made it back to the cars just as a heavy thunderstorm began, and drove in the rain back to Chillicothe. After a buffet supper, we were treated to an illustrated talk on the distribution of plants in Ohio by Dr. Ronald Stuckey, of Ohio State University.

Although Monday was Labor Day, and some of us were fearful of the traffic, we found that we were probably the longest line of cars some of the local residents had seen. Our caravan of 23 cars travelling down gravel roads brought a number of folks out onto their porches to see what was going on. This day was spent in three wooded ravines, all in Hocking County, leaving time for the drive to the A.I.B.S. meetings at Columbus.

The first stop was near Laurelville. Here both gametophytes and sporophytes of *Trichomanes boschianum* were found on overhanging cliffs. This area was also good for hybrids. Dale Hagenah discovered the rare *Cystopteris* × *tennesseensis* on a sandstone ledge. Several plants of *Dryopteris* × *neowherryi* were found growing with the parents *D. goldiana* and *D. marginalis.* A patient search by many members failed, however, to turn up any *Asplenium* × *kentuckiense,* although the parents, *A. pinnatifidum* and *A. platyneuron,* were found in close proximity.

At the lunch stop, Conkle's Hollow State Park, several more discoveries were made. Dr. W. H. Wagner, Jr., exploring along the stream, discovered several species of *Dryopteris* and the hybrid *D.* × *slossonae* (*D. cristata* × *marginalis*). Donald Huttleston found *Ophioglossum vulgatum,* and Julie Multer found *Botrychium lanceolatum;* both of these represented new county records. Several other Botrychiums were also found in the wet bottomlands along the stream.

At Pipeline Hollow we saw more *Lycopodium porophilum* and its hybrid with *L. lucidulum.* Another find was *Botrychium ternatum,* a species with which Dr. Wagner is currently working.

The trip was organized and led by Dr. and Mrs. Warren H. Wagner, Jr., and Dr. Richard Hauke. They had planned enough time at each stop so that we had ample time to explore, and had picked very interesting areas. We are grateful to several Ohio botanists who helped locate the areas and plants: Dr. Ronald Stuckey, Prof. William Adams, and Mr. Floyd Bartley. Mr. Bartley has been studying this interesting area for many years. We saw 43 species, and the group was quite successful in finding five hybrids in four genera. The plants seen, including these hybrids, were: *Equisetum arvense, Lycopodium lucidulum, L. porophilum, L. lucidulum* × *porophilum, L. obscurum, Selaginella apoda, Botrychium dissectum* (both forma *dissectum* and forma *obliquum*), *B. lanceolatum, B. oneidense, B. ternatum, B. virginianum, Ophioglossum vulgatum, Osmunda cinnamomea, O. claytoniana, Lygodium palmatum, Trichomanes boschianum, Adiantum pedatum, Asplenium montanum, A. pinnatifidum, A. platyneuron, A. rhizophyllum, A. trichomanes, A.* × *trudellii, Athyrium asplenioides, Athyrium pycnocarpon, Athyrium thelypterioides, Cystopteris* *bulbifera, Cystopteris fragilis, C. × tennesseensis, Dennstaedtia punctilobula, Dryopteris cristata, D. goldiana, D. intermedia, D. marginalis, D. spinulosa, D. × neowherryi, D. × slossonae, Pellaea atropurpurea, P. glabella, Polypodium virginianum, Polystichum acrostichoides, Thelypteris hexagonoptera, T. noveboracensis, Vittaria lineata* (gametophyte), *Woodsia obtusa, Woodwardia areolata*, and *W. virginica.*

Participants were from 14 states. Several students from Ohio State University joined in for one or both days. The leaders were: Dr. and Mrs. Richard Hauke (R.I.), Dr. and Mrs. Warren H. Wagner, Jr. (Mich.). The local experts were Dr. Clara Mae Frederick, Mr. Floyd Bartley, Prof. William Adams, Dr. Jane Forsyth, and Dr. Ronald Stuckey. The participants were Mr. Robert Aborn (N.J.), Mrs. Lenette Atkinson (Mass.), Mr. Emmett Barnhart (Ohio), Prof. Harriette Bartoo (Mich.), Mr. and Mrs. Harold Boecher (Ohio), Miss Florence Branum (Ohio), Dr. and Mrs. Clair Brown (La.), Mr. and Mrs. Harry Butler (Ohio), Mr. Tom Duncan (O.S.U.), Dr. Mildred Faust (N.Y.), Mrs. Elfreda Finch (N.J.), Mr. Gerald Gastony (Mass.), Mrs. Alice Gobin (Calif.), Mr. and Mrs. Dale Hagenah (Mich.), Mr. Neill Hall (Wash.), Mr. and Mrs. Orve Hedden (Ohio), Mr. and Mrs. Charles Hildreth (Ohio), Dr. Donald Huttleston (Pa.), Mr. James Jones (Ohio), Miss Edna Kidry (O.S.U.), Dr. Irving Knobloch (Mich.), Mr. and Mrs. Thomas Liston (N.Y.), Dr. Robert Lommasson (Neb.), Mr. and Mrs. William Meinders (Ohio), Mr. and Mrs. Blaine Miller (Pa.), Mr. Alan Montgomery (Ohio), Dr. James Montgomery (N.J.), Miss Julie Multer (Ohio), Mr. and Mrs. Patrick Oliver (Ind.), Mr. L. Phillips (O.S.U.), Mr. E. L. Pitner (Ohio), Mr. and Mrs. W. E. Pouker (Pa.), Mr. Victor Ries (Ohio), Miss Jan Schnepp (O.S.U.), Mr. Mike Slavin (Conn.), Miss Eva Sobol (N.Y.), Miss Susan Stephenson (Mich.), Dr. Dean Whittier (Tenn.).—James D. Montgomery, *Biology Department, Upsala College, East Orange, New Jersey 07019.*

Statement of Ownership, Management and Circulation

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The statements made above are certified to be correct, and are signed by: David B. Lellinger, editor-in-chief of the American Fern Journal on October 1, 1968.

Eb

Vol. 59 April–June, 1969 No. 2

American Fern Journal

A QUARTERLY DEVOTED TO FERNS

Published by the
AMERICAN FERN SOCIETY

CONTENTS

The American Fern Society

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American Fern Journal

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Matter for publication should be addressed to the Editor-in-Chief.

Changes of address, applications for membership, subscriptions, orders for back numbers should be addressed to the Treasurer.

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Back volumes $5.00 to $6.25 each; single back numbers of 64 pages or less, $1.25; 65-80 pages, $2.00 each; over 80 pages, $2.50 each; Cumulative Index to Volumes 1-25, 50 cents. Ten percent discount on orders of six volumes or more.

Library and Herbarium

Dr. W. H. Wagner, Jr., Department of Botany, University of Michigan, Ann Arbor, Michigan 48104, is Librarian and Curator. Members may borrow books and specimens at any time, the borrower paying all shipping costs.

Spore Exchange

Mr. Neill D. Hall, 1225 Northeast 95th Street, Seattle, Washington 98115, is Director. Spores exchanged and collection lists sent on request.

Gifts and Bequests

Gifts and bequests to the Society enable it to expand its services to members and to others interested in ferns. Herbarium specimens, botanical books, back issues of the JOURNAL, and cash or other gifts are always welcomed, and are tax-deductible. Inquiries should be addressed to the Secretary.

American Fern Journal

Vol. 59 April–June, 1969 No. 2

Pteridophyte Checklist of Ashtabula, Trumbull and Mahoning Counties, Ohio

Carl F. Chuey and Nicholas Sturm

The pteridophytes reported herein were collected for the initial collection of the Herbarium of Youngstown State University during 1966–68 in Ashtabula, Trumbull, and Mahoning Counties, an area in northeastern Ohio of extensive agriculture but more recently one of increased urbanization and industrialization. Scattered ravines and residual woodlots on many farms provide sites for sustaining the flora, but the woodlots have been pastured and the ravines have been used for recreation. Continued urbanization and projected impoundments will probably further reduce the suitable sites and, accordingly, the number of extant species in these counties.

Many taxa reported in early years are no longer represented at sites reported (Rogers, 1904; Vickers, 1909, 1910a, b, c; Galaida, 1941; Cusick, 1967), and more will no doubt be lost, although an appreciable pteridophyte flora is becoming reestablished in many old, abandoned fields. If urbanization becomes stabilized, some of the species may expand into these areas extensively.

Except as noted below, collection sites were selected by field exploration, but may not represent the best habitats in the region. All previously reported sites have been checked.

The collection sites are shown in *Fig. 1.* Pymatuning State Park and Camp Whitewood were the main collection sites in Ashtabula County. Trumbull County has not been as widely explored as Ashtabula, but most of the pteridophytes from the county were collected during a survey of the basic vegetation and development of trails throughout the Trumbull Arboretum of Youngstown State University.

Volume 59, No. 1 of the Journal, pp. 1–40, was issued March 28, 1969.

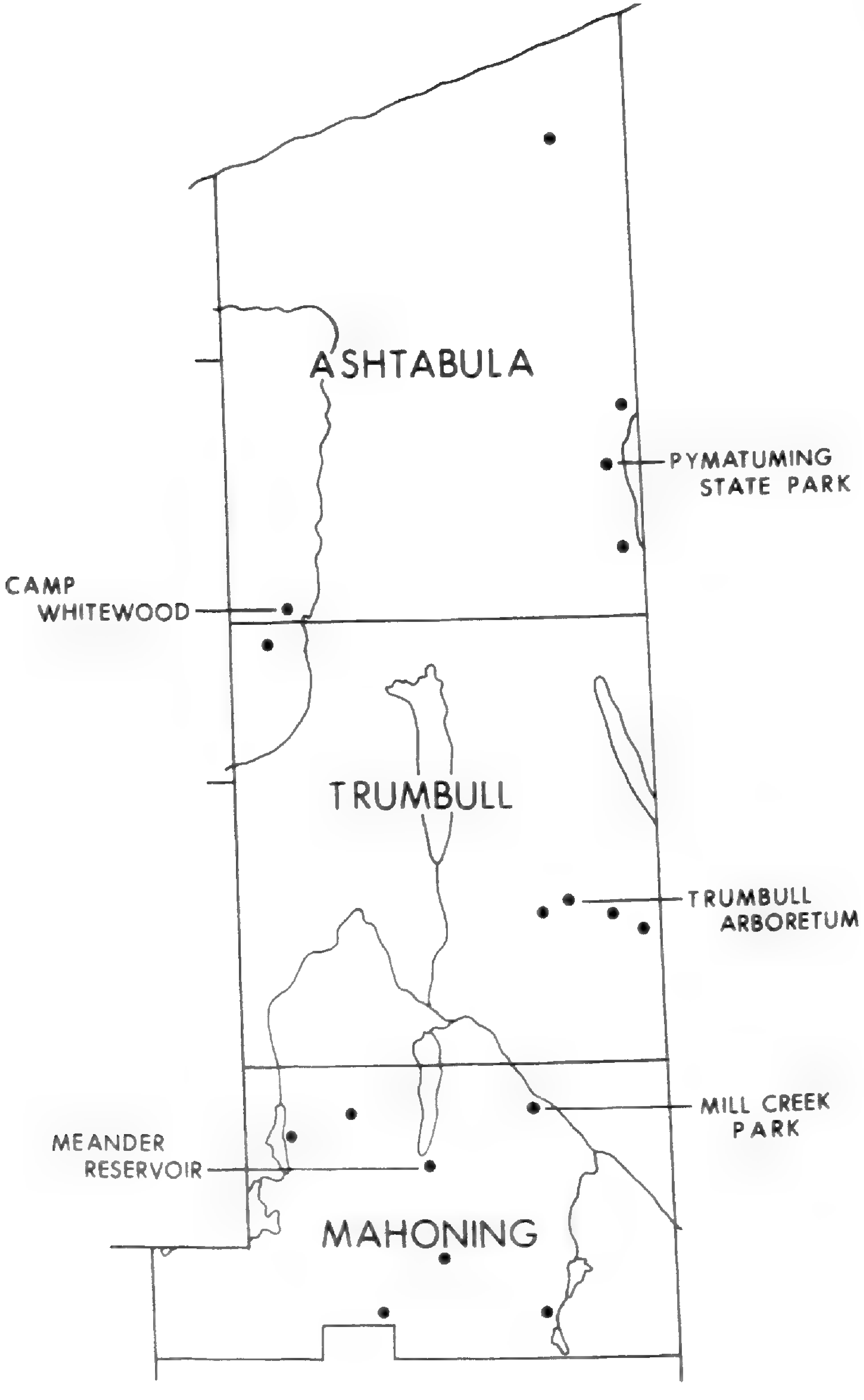

Fig. 1. Collection Sites in the Three-county Region

TABLE I. PTERIDOPHYTE CHECKLIST OF ASHTABULA, TRUMBULL, AND MAHONING COUNTY, OHIO

Taxon	*A*	*T*	*M*
LYCOPODIACEAE			
Lycopodium clavatum L.	X	X	
L. complanatum var. flabelliforme Fern.	X	X	X
L. obscurum L.	X	X	
EQUISETACEAE			
Equisetum arvense L.	X	X	X
E. hyemale var. pseudohyemale (Farw.) Morton		X	X
OPHIOGLOSSACEAE			
Botrychium dissectum Spreng. var. dissectum		X	X
B. dissectum var. obliquum (Muhl.) Clute	X	X	X
B. virginianum (L.) Swartz	X	X	X
OSMUNDACEAE			
Osmunda cinnamomea L.	X	X	X
O. claytoniana L.	X	X	X
O. regalis var. spectabilis (Willd.) Gray	X	X	X
POLYPODIACEAE			
Adiantum pedatum L.	X		X
Asplenium platyneuron (L.) Oakes		X	
Athyrium filix-femina var. michauxii Mett.	X	X	X
A. pycnocarpon (Spreng.) Tidest.	X		
A. thelypterioides (Michx.) Desv.	X		
Cystopteris bulbifera (L.) Bernh.	X		X
C. fragilis (L.) Bernh.	X		
Dennstaedtia punctilobula (Michx.) Moore		X	X
Dryopteris austriaca var. intermedia (Muhl.) Morton		X	X
D. goldiana (Hook.) Gray	X		
D. marginalis (L.) Gray		X	X
Matteuccia struthiopteris (L.) Todaro	X	X	X
Onoclea sensibilis L.	X	X	X
Polypodium vulgare var. virginianum (L.) Eaton		X	X
Polystichum acrostichoides (Michx.) Schott	X	X	X
Pteridium aquilinum var. latiusculum (Desv.) Underw.	X	X	X
Thelypteris noveboracensis (L.) Nieuwl.	X	X	X
T. palustris Schott	X	X	
T. phegopteris (L.) Slosson	X		

The pteridophytes in Mahoning County were collected in many areas, including Mill Creek Park and Meander Reservoir. The latter area was selected because it has been inaccessible to the general public since about 1932, and Mill Creek Park was selected because it has been reported previously in the literature (Rogers, 1904; Vickers, 1910b; Galaida, 1941).

The nomenclature in *Table 1* follows that of Gleason (1963). Additional works consulted for obscure taxa were Billington (1962), Cobb (1960), Fernald (1950), Vannorsdall (1956), and Wherry (1961).

Five families, 16 genera, and 30 species and varieties were found in the three county region. Twenty-two were in Ashtabula County, 23 in Trumbull County, and 22 in Mahoning County. All specimens were deposited in the Herbarium of Youngstown State University (YUO).

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DEPARTMENT OF BIOLOGY, YOUNGSTOWN STATE UNIVERSITY, YOUNGSTOWN, OHIO, 44503.

The First Record of Asplenium septentrionale (L.) Hoffm. in Oregon[1]

FRANK A. LANG

On October 26, 1968 I discovered a population of about 70 plants of *Asplenium septentrionale* (L.) Hoffm. at Copeland Creek on the North Umpqua River in Douglas County, while on a trip to collect the endemic monotypic *Kalmiopsis leachiana* (Hend.) Rehder, an interesting member of the heath family native only to southwestern Oregon. About sixty plants of *A. septentrionale* were growing in rock crevices around the south side of a badly weathered vescicular quartz boulder just above a number of *Kalmiopsis* plants. About 75 feet down the hill another rock of similar composition was discovered with another eleven plants on it. The site is at 2,320 feet elevation with a southerly exposure although the boulders are shaded by Douglas fir, *Pseudotsuga menziesii* (Mirb.) Franco, and Sugar Pine, *Pinus lambertiana* Dougl. In Colorado *A. septentrionale* is found at higher elevations, 5,000 to 8,000 feet (Harrington, 1964).

This distinctive amphi-atlantic species of *Asplenium* is found in Europe, Central Asia, and Western North America. In the Western Hemisphere it is known from the east slope of the Rocky Mountains from South Dakota and Wyoming south to western Oklahoma New Mexico, Arizona, and Baja California. Kearney and Peebles (1960) report it from California, and Hulten (1958) shows it on his distribution map as occurring in central California near the Nevada border, although no specimens are cited by either source. The California locality is probably the collection by J. T. Howell (*17803*) reported by Ewan (1943). Howell collected *A. septentrionale* in crevices of granite rocks above Columbine Lake below Sawtooth Pass, east of Mineral King in Tulare County south

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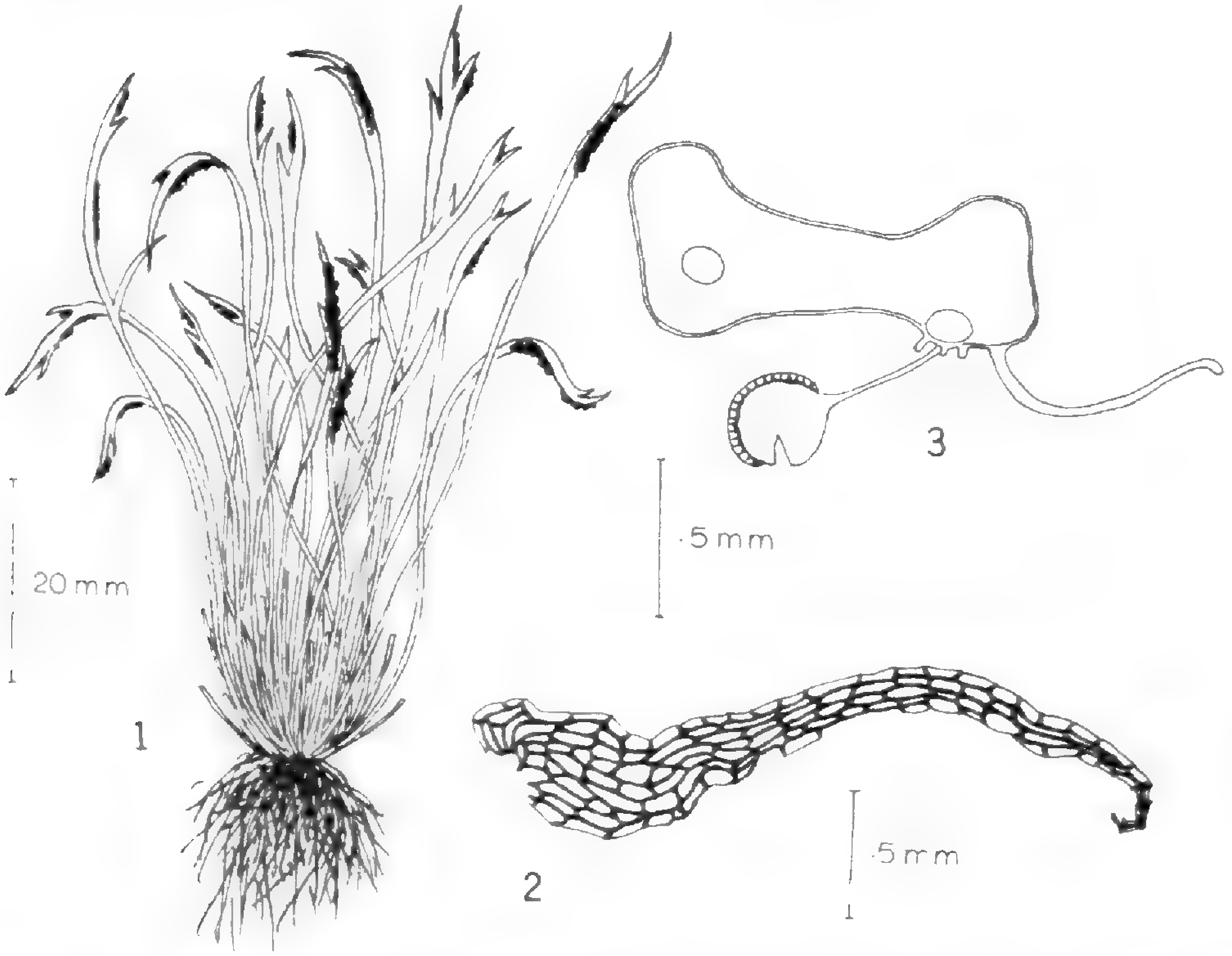
[1] Partial financial support by Southern Oregon College is gratefully acknowledged. The determination of the rock composition by Dr. William Purdom and Dr. Richard Wilson using the SOC science division X-ray diffractometer is also acknowledged.

of Sequoia National Park. *Asplenium septentrionale* is not mentioned by Munz (1959) as being present in California.

The species is not reported in the Oregon flora by Peck (1961), and to my knowledge this is the first record of the species in the state. With the nearest known locality in California over 600 miles to the south, the prevailing westerly wind pattern does not favor the establishment of the species in Oregon by wind-blown spores over that distance. Since the plant is rather inconspicuous and bears a striking resemblance to tufts of grass, it is possible that the species does occur in Northern California but has been overlooked by collectors. The Oregon population probably represents the northernmost known locality in its distribution west of the Rocky Mountains.



Figs. 1–3. Asplenium septentrionale (L.) Hoffm. drawn from Lang 380 Fig. 1. Habit sketch. Fig. 2. Rhizome scale. Fig. 3. Cross section of sorus showing sporangium with the indusium at the lower right.

Because of the distance of the ferns from human habitation it seems unlikely that it is an introduced species in Oregon. It is likely a relict of a past flora that still persists in the area, such as the species of *Kalmiopsis* mentioned above.

Many of the plants found at Copeland Creek were fertile and abundantly producing spores. The plants range in age from sterile sporelings to mature plants with sori, indicating the reproductive capabilities of the plants.

The ferns at Copeland Creek narrowly missed extermination. Two cutover areas occur to the north and south of the plants; had they been a few hundred yards in either direction the plants would surely have been destroyed. Steps are being taken by the U.S. Forest Service to see that the site will remain undisturbed. It is hoped that the discovery of this species in Oregon will encourage collectors on the west coast to watch for this rare and unusual fern.

Specimens examined were: COLORADO: *T. S. Brandegee* (ORE). MEXICO: Lower California, San Pedro Martir Mountain, *T. S. Brandegee* (ORE). OREGON: Douglas Co.: North Umpqua River, Copeland Creek, *F. A. Lang 380* (OSC, SOC, UBC). WYOMING: Albany Co.: Fish Creek, Wyoming-Colorado Border, *E. B. & L. B. Payson 2508* (OSC).

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The Fern Collections in Some European Herbaria, III

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Conservatoire et Jardin Botaniques, Geneva

The Conservatoire et Jardin Botaniques of Geneva have a long and illustrious history. Although there had been several small private botanical gardens in Geneva in earlier years, the publicly owned garden of the city dates from 1817, when the City Council approved a garden and five trees were planted as a symbol on the site chosen on the Promenade des Bastions Bourgeois. The garden was opened officially to the public April 3, 1819. It was the result of efforts by the most celebrated of Swiss botanists, Augustin Pyramus de Candolle, who was appointed the first Director and who remained in his post until his death in September, 1841.

The citizens of Geneva contributed 600 species of plants and sufficient money to construct an orangery, two greenhouses, and an aquatic garden, in addition to the principal gardens. Under the energetic direction of de Candolle, the number of species planted was raised to 4,500 within three years by exchange with Paris and other botanical gardens. The ambitious program of the garden included instruction in botany, horticulture, and agriculture, the introduction of new crops and ornamental plants, and research.

The first herbarium was de Candolle's own, which was large for a private herbarium and which became much larger with the years. It served as the basis of the monumental "Prodromus Systematis Naturalis Regni Vegetabilis," known to botanists the world over as merely *the* "Prodromus." Among the innumerable collectors represented are Patris, Lhotzsky, d'Orbigny, Perrottet, de la Sagra, Balbis, Bertero, and Berlandier. Among the treasures are 1370 copies of the original drawings of Mexican plants by Sessé and Moçiño made in the late eighteenth century but never published. De Candolle based many new species on these drawings alone. The herbarium continued to be built by his son, Alphonse de Candolle, and grandson, Casimir de Candolle, until it reached about 300,000 specimens. The "Prodromus" Herbarium is now maintained as a separate unit. The whole herbarium was photographed recently, and the photographs are available for sale. They are invaluable in deciding on types and lectotypes.

De Candolle himself did not work much on ferns, other than those of France. The only American species that he described that I can recall at the moment is *Trichomanes osmundoides* DC., a fairly widespread and characteristic fern. Among the ferns are many L'Herminier specimens from Guadeloupe determined by Fée, which may be types or suitable lectotypes for some of the numerous Fée species.

In 1831 Alphonse de Candolle was appointed Deputy Director, and after his father's death he became Director until 1849. He was succeeded by Georges F. Reuter, who was Director from 1849 until his death in 1872. Reuter must have been something of a child prodigy, for he published his first book, an account of the spontaneous flora of the vicinity of Geneva, when he was only 16 years of age. A confused period followed while Jacques Brun was Director of the garden and the conservatory was under a different city administration.

Meantime, Benjamin Delessert had bequeathed his enormous herbarium to the city of Geneva in 1869 and Jean Müller had been appointed curator in 1874. Since there was an older Jean Müller, also a botanist, the younger man called himself Müller Argoviensis (a Latinized adjective derived from his native town of Aargau, Switzerland), and is usually cited as "Muell. Arg." He published on various families such as Resedaceae and Apocynaceae, but was especially an authority on lichens and on the Euphorbiaceae, which he elaborated for the "Prodromus." When Brun retired in 1879 Müller was appointed Director of the Jardin Botanique and brought along the Delessert Herbarium, which became the herbarium of the garden. Although hundreds of thousands of specimens have been added since the time of Delessert, the general herbarium is still officially the "Delessert Herbarium."

Jules Paul Benjamin Delessert (1773–1847), was the son of a wealthy family of Lyon, France. Etienne Delessert, his older brother, had begun collecting plants in 1788, and Benjamin accompanied him on his collecting trips in France, Switzerland, England, and Scotland. Etienne had begun a larger worldwide herbarium by purchasing collections from Japan, India, Ceylon, and Africa. Unfortunately, he died in New York at the early age of 25 from yellow fever. Benjamin continued with the building up of his herbarium for the rest of his life. He collected rather widely himself, but acquired most of his herbarium by purchases and exchanges. He was not himself a professional botanist, although he was the nominal author of a sumptuous publication, the "Icones Selectae Plantarum," in five folio volumes (1820–1846). The descriptions in this work were written by de Candolle.

The first designated curator of Delessert's Herbarium was Achille Richard (1794–1852), a famous professor of the Sorbonne, authority on the flora of Abyssinia and New Zealand, on the families Orchidaceae and Rubiaceae, and especially on medicinal plants. He was curator from 1817 to 1827, and was succeeded by Antoine Guillemin (1796–1842), remembered especially for the "Florae Senegambiae Tentamen" and the "Zephyritis Taïtensis," the first enumeration of the plants of Tahiti. After the death of Guillemin, Antoine Lasegue became curator in 1842. Lasegue produced in three years a remarkable book, the "Musée Botanique de Delessert," one of the most elaborate accounts ever written about a particular herbarium. It is still important today for the accounts of the travels of the various collectors represented in the herbarium, and of many not represented also.

The principal herbarium first acquired by Delessert was that of Louis Guillaume LeMonnier, of the Jardin des Plantes, Paris. which came to Delessert in 1803. Lasegue does not give any details regarding the acquisition of this herbarium, which really should have remained in Paris. I can imagine however that there was some bitterness toward Paris on the part of LeMonnier, who had been dismissed as professor in the Jardin des Plantes in 1786. The LeMonnier Herbarium contained over 10,000 specimens and was rich in types. It included 5,000 specimens of Commerson, collected on his trip around the world with Bougainville in 1766–1769, and many specimens of Michaux collected in the United States in 1785–1796, and of René Desfontaines from Africa.

The single largest herbarium obtained by Delessert was the herbarium built up by Johannes Burmann (1707–1779) and his son Nikolaus Laurens Burmann (1733–1793), which was purchased in Amsterdam. It contained the originals on which Burmann's "Thesaurus Zeylanicus" (1737) was based, mostly or altogether plants that had been collected by Paul Hermann in Ceylon between 1670 and 1677. Linnaeus worked over these same plants; they are the basis for Linnaeus' own "Flora Zeylanica" (1747). I have not seen these plants, which are mounted in a large, bound folio volume. In addition to the Burmanns' own collections, the herbarium contains plants from Breyn, Kleinhoff, Oldenland, Houttuyn, Schmidel, Hartog, Allioni, Haller, and even some of Linnaeus, who sent a duplicate set of his Lapland collections to Burmann, and these are thus isotypes of the species described in Linnaeus' "Flora Lapponica" (1737).

The Thuillier Herbarium obtained by Delessert in 1827 contained specimens from L. C. Richard, Jussieu, and many of the French voyagers. Many of these specimens were studied and annotated by Desvaux.

Delessert purchased what may have been the largest portion of the Lambert Herbarium when it was put up for sale in 1842. The specimens obtained included many from Roxburgh, Captain Beechey, Masson, Drummond, and others.

The Delessert Herbarium contained in addition many plants from Thunberg (South Africa, Java, Japan), Gaudichaud, Perrottet, Sieber, Wallich, and Roxburgh. It has the original herbarium of Etienne Pierre Ventenat, which contains the originals of Ventenat's magnificent "Jardin de la Malmaison" and duplicates from Vahl, Schrader, Cavanilles, Delile, Villars, Balbis, and others. Another important herbarium is that of Palisot de Beauvois, which contains part of the original collections obtained in Oware and Benin in 1786–1798.

Müller remained as Director of the garden until his death in 1896, at which time Jean Briquet was appointed to the post. The removal of the garden to a suburban location had been proposed some time before by Alphonse de Candolle, but nothing had been done. The estate "Ariana" had been willed to Geneva, and the city council decided to utilize it for a new botanical garden. It is situated on the shores of Lake Geneva only a short distance away from the city. It had already been planted as a park and a number of old trees were already there—an altogether suitable site. Construction of the new garden began in 1902, and the new garden was inaugurated September 26, 1904. The Conservatory was not moved until 1908. In addition to his administrative duties, Briquet found time to publish a good deal of botanical work and was a recognized authority on nomenclature.

Briquet died in 1931 and was succeeded by B. P. B. Hochreutiner, who had been second in charge for 35 years. When Hochreutiner retired in 1943, Charles Baehni became Director. He had been an assistant since 1932. Under Baehni's efficient direction the garden continued to progress. I have good reason to feel a personal regard for Baehni, for when I was in Geneva in 1954 I was unfortunately obliged to have an emergency appendectomy. While I was recuperating in the Clinique Beaulieu, Baehni came to visit me many times and kept my room always full with fresh flowers from the botanical garden, very unusual flowers, too, to be seen in a hospital. Baehni died suddenly in 1964 at a relatively early age, and was succeeded by the present Director, Jacques Miège. Much of the historical data regarding the garden I have taken from a recent publication by Dr. Miège, "Le Jardin botanique de Genève: 150 ans d'histoire," published in celebration of the 150th anniversary of the garden.

The third large herbarium now belonging to Geneva is that of Boissier and Barbey-Boissier, which was long maintained in a separate building, but which is now integrated with the Delessert Herbarium, although still kept in separate pigeonholes. The original herbarium used for the "Flora Orientalis," however, is going to be kept permanently separate.

Pierre Edmond Boissier (1810–1885) was a native of Geneva, and attended the university there. He became the most illustrious student of de Candolle. Probably on the advice of Webb, he determined to study the flora of Spain, which was relatively unknown at the time. He started out in 1837 for a tour of Spain. In Madrid he made the acquaintance of Mariano Lagasca, who was the director of the botanical garden in Madrid, and who gave him some of his collections, which are still in the Boissier Herbarium. Boissier collected about 100,000 specimens in the year in Spain, representing more than 1,800 species, and in the following year published his first paper in which he described some 200 new species that he had discovered. He continued to work on the Spanish flora for many years, but gradually extended his interests to northern Africa and the Near East. His collecting trips took him to Algeria, Egypt, Palestine, Syria, and Arabia, as well as many parts of Europe. His wife accompanied him on some of his trips. She died suddenly in Grenada, Spain, in 1849. Thereafter, Boissier devoted himself exclusively and even more assiduously to botany for about the next forty years, and became one of the most productive of botanists. He treated the family Plumbaginaceae in de Candolle's "Prodromus" and provided the account of the genus *Euphorbia*, which included 723 species. Although this was over a hundred years ago, no one since has ventured to undertake another complete treatment of *Euphorbia*. After this he began work on his masterpiece, the "Flora Orientalis," published in five large volumes between 1867 and 1884, with 5386 pages and detailed descriptions of 11,876 species, among them 757 in *Astragalus* alone. The area covered included all that between Egypt and India. Altogether Boissier established 5990 new species, a figure near that of de Candolle (6369 new species), and one which is not likely to ever be equalled again, not with "good" species, for Boissier described "Linnaean type" species and not "Jordanons," apomicts, microspecies, or such like.

Boissier was closely associated with de Candolle and other botanists, but he was never associated with the Jardin Botanique as a staff member except possibly in an honorary capacity. He amassed an immense private herbarium, especially, of course, of specimens from the Near East, including collections from Bunge, Kotschy, Haussknecht, and many others. Boissier is honored today by the journal "Boissiera."

William Barbey (1842–1914) was a native also of the region around Geneva. He started out to be an engineer, but after his marriage to Caroline, the daughter of Edmond Boissier, he devoted the rest of his life to botany. He published many small botanical papers in his later years, but is best known for his work in building up the Boissier Herbarium, which he inherited from Boissier. He later took the name Barbey-Boissier. He founded the "Bulletin de l'Herbier Boissier," which appeared in annual large volumes between 1893 and 1908. He appointed Eugene Autran as curator of the herbarium (between 1887 and 1909) and then Gustave Beauverd after 1909. Among the valuable collections acquired by Barbey-Boissier are hundreds of hepatics from Stephani, including the types of most of the species, the moss herbaria of Hedwig and Schwaegrichen, the lichens of Müller Arg., the types of Gaudin's "Flora Helvetica," and many others, including a precious collection of autographs gathered by Baron Cesati.

The Conservatoire et Jardin Botaniques have issued publications under several titles during their long history. At present the contributions from the staff are published in the journal "Candollea."

I have visited Geneva several times and I have always enjoyed working in the herbarium, a feeling that is shared by all other botanists that I have talked with who have worked there. Visitors are made to feel welcome and are given free use of the collections. The library is fine and quite complete, especially for the hard-to-come-by "Index Seminum" publications that were issued by many botanical gardens in the nineteenth century and which often contained original descriptions. At the time of my first visit, the ferns were apparently not often consulted, for they were not housed with the other collections but were in the attic of a small house nearby, perhaps a hazardous place since the building was certainly not fireproof. They are now in the basement of the main herbarium building and are housed in an unique way for any herbarium in the world, a system they call "Compactus." I understand that this was devised originally for the compact shelving of books, but it is adapted to herbarium specimens very well also. It is a little hard to describe, but is illustrated in the journal "Taxon" (vol. 9, pp. 62 and 63). The specimens are in large cases that are open and two-faced. When not in use the cases are next to each other, with no corridor at all between them, and thus one can get almost twice as many cases into the same space than if there were corridors. The cases are on rollers. When one turns on a motor at the end of the room, one can move these cases singly or even several at a time without effort, even perhaps with one finger, even though the cases weigh hundreds of pounds. One thus makes an open corridor where one wishes to be. The system works very well indeed. A drawback to its general adoption is the great weight when so many cases are compacted into such a small space, and so basements may be the most suitable for this arrangement. I understand that they would like to use the "Compactus" on other floors of the herbarium in Geneva in order to relieve the congestion, but the old building will not stand the weight. I shudder to think of what might happen if the cases were suddenly rolled together while someone was working in a corridor!

The fern collection contains examples from all the historical collections mentioned above. Most interesting to me are those of Burmann, Roxburgh, Houttuyn, and Thunberg. I hope to publish a paper on some of these types. A good many of the ferns from the original Delessert Herbarium were sent to Kunze, who annotated many of them. Since the Kunze Herbarium is now destroyed in Leipzig, these Geneva specimens are suitable lectotypes for many of Kunze's species. Spring studied the Lycopodiums and Selaginellas and cited them in his monograph, and these too are important types. Of special interest also is the very complete set of Zollinger's Javan collections, which also were studied and annotated by Kunze.

(To be continued)

Occurrence of the European Polypodium australe Fée on San Clemente Island, California

ROBERT M. LLOYD AND JANET E. HOHN

Recent studies in Europe and the United States have accumulated considerable knowledge on the proper delimitations and evolution of the *Polypodium vulgare* complex. Shivas (1960a, b) has shown that the *P. vulgare* complex in Europe consists of three well-defined species. Recent discoveries by Fosberg (1968) indicate that at least one of these European entities may occur on the North American continent.

The complex in Europe includes *P. australe* Fée, a diploid ($n = 37$) species found in the immediate Mediterranean region and as far north as the southern British Isles; *P. vulgare* L., a tetraploid ($n = 74$) species distributed throughout Scandinavia, Finland, and the mountainous regions of the European continent; and *P. interjectum* Shivas, a hexaploid ($n = 111$) taxon found on the European continent to the south shore of the Baltic Sea and throughout the British Isles. These species are easily distinguished from one another by a combination of characters including chromosome number, presence or absence of paraphyses, oval or circular sori, number of indurated annulus cells, and inflection of the basal pinnae (see *Table I*).

Work by Manton (1951, 1957), Manton and Shivas (1953), Lloyd (1962, 1963), and Lloyd and Lang (1964) has done much to elucidate the relationships of the species found in North America. These include *Polypodium virginianum* L., with diploid and tetraploid races, occurring from the eastern seaboard to British Columbia; *P. hesperium* Maxon, a species also with diploid and tetraploid races, found from British Columbia south to Arizona; *P. glycyrrhiza* D. C. Eaton, a diploid species, distributed from central California north to Alaska; *P. scouleri* Hook. & Grev., a diploid coastal species which is the most distinct of the complex, occurring only on Guadalupe Island, Santa Cruz Island, Morro Rock in the southern portion of its range and on the mainland from Monterey County north to British Columbia; and *P. californicum* Kaulf., a species with two cytological races, the diploid occurring from Baja California to the San Francisco Bay region, and the tetraploid distributed from Monterey County north to Humboldt County, largely in the overlap between the distributions of *P. glycyrrhiza* and diploid *P. californicum. Table II* summarizes many of the salient features of the Californian species.

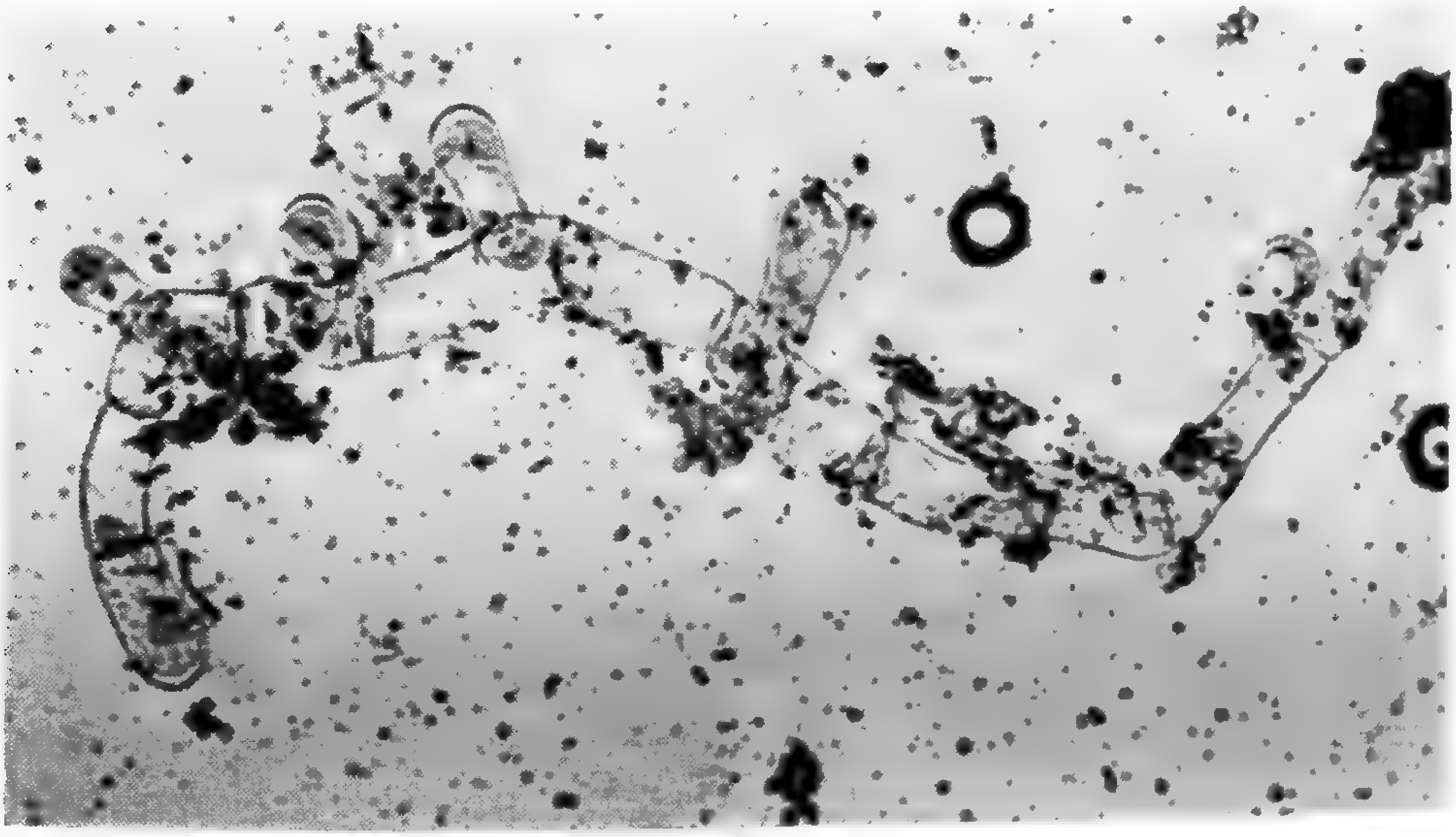

FIG. 1. YOUNG PARAPHYSIS OF POLYPODIUM AUSTRALE FROM SAN CLEMENTE ISLAND, CALIFORNIA (× 160).

Recent collections of *Polypodium* by Peter H. Raven made during the course of his investigations of the flora of San Clemente Island (Raven, 1963) have brought into cultivation a plant which is morphologically similar to *Polypodium australe* of southern Europe (*Lloyd & Hohn 4420*, UC, from a cultivated plant originally collected in a canyon in the vicinity of Wilson Cove, San Clemente Island, at about 250 feet elevation, on 12 April 1962, by P. H. Raven). An herbarium specimen collected by Raven at the time (*Raven 17341*, UC) from the same location has proved to be typical *P. californicum*.

Polypodium australe can be distinguished easily from all other known species of the *P. vulgare* complex by the presence of dis-

TABLE I. CHARACTERISTICS OF THE EUROPEAN SPECIES OF THE POLYPODIUM VULGARE COMPLEX (FROM SHIVAS, 1960a, b).

Character	*P. australe*	*P. vulgare*	*P. interjectum*
Chromosome number	$n = 37$	$n = 74$	$n = 111$
Frond shape	ovate	lanceolate	ovate
Lower pinnae	inflexed	not inflexed	inflexed
Sorus shape	oval	circular	oval
Indurated annulus cells	2–8 (mean = 5)	7–17 (mean = 12)	4–13 (mean = 9)
Paraphyses	present	absent	absent

TABLE II. CHARACTERISTICS OF THE CALIFORNIAN SPECIES OF THE POLYPODIUM VULGARE COMPLEX (FROM LLOYD, 1962, 1963; LLOYD AND LANG, 1964).

Character	*P. californicum*	*P. glycyrrhiza*	*P. scouleri*	*P. hesperium*
Chromosome number	$n = 37, 74$	$n = 37$	$n = 37$	$n = 74$
Frond shape	ovate-lanceolate	ovate-lanceolate	ovate	linear-lanceolate
Lower pinnae	not inflexed	not inflexed	not inflexed	not inflexed
Sorus shape	circular to oval	circular	circular to oval	circular
Indurated annulus cells	10–21 (mean = 13)	9–24 (mean = 13)	11–20 (mean = 14)	9–24 (mean = 13)
Paraphyses	absent	absent	absent	present (rare)

tinctive, elongate, uniseriate, multicellular paraphyses with clavate branches, as well as only 2–8 (mean = 5) indurated annulus cells (cf. *Tables I* and *II* for comparisons with other species). Paraphyses found in the plant from San Clemente Island (*Fig. 1*) are identical to those pictured by Martens (1950a, *figs. 1–3*) and Shivas (1960a, *Plate 3, figs. 14, 15*) for *P. australe.* The paraphyses in *P. australe* are easily distinguished from those found in *P. hesperium* and *P. virginianum.* Paraphyses in these latter two species have a slender stalk terminated with a knob-like dark-colored head with two-celled glandular hairs (Manton and Shivas, 1953, *figs. b, d;* Martens, 1947; Martens, 1950b, *figs. 1–12;* Morton and Neidorf, 1954; Shivas, 1960a, *fig. 16*). The plant from San Clemente Island is diploid with 37 bivalents at meiotic metaphase I, and agrees with all of the other characteristics for *P. australe* as listed by Shivas (1960a, b).

Investigations of other material collected on the island has yielded no other specimens of *P. australe,* and field investigations are needed to determine its actual distribution.

The occurrence of *P. australe* on San Clemente Island can most likely be explained as a chance introduction of spores carried on hides and hair of European grazing animals which were commonly introduced onto the Channel Islands during the 18th and 19th century. But, the unusual distribution of another Channel Island genus, *Lavatera,* which is also found in the Mediterranean region as well as the Canary Islands, Australia, and Central Asia, might lend credence to the hypothesis that *P. australe* is a relict native species.

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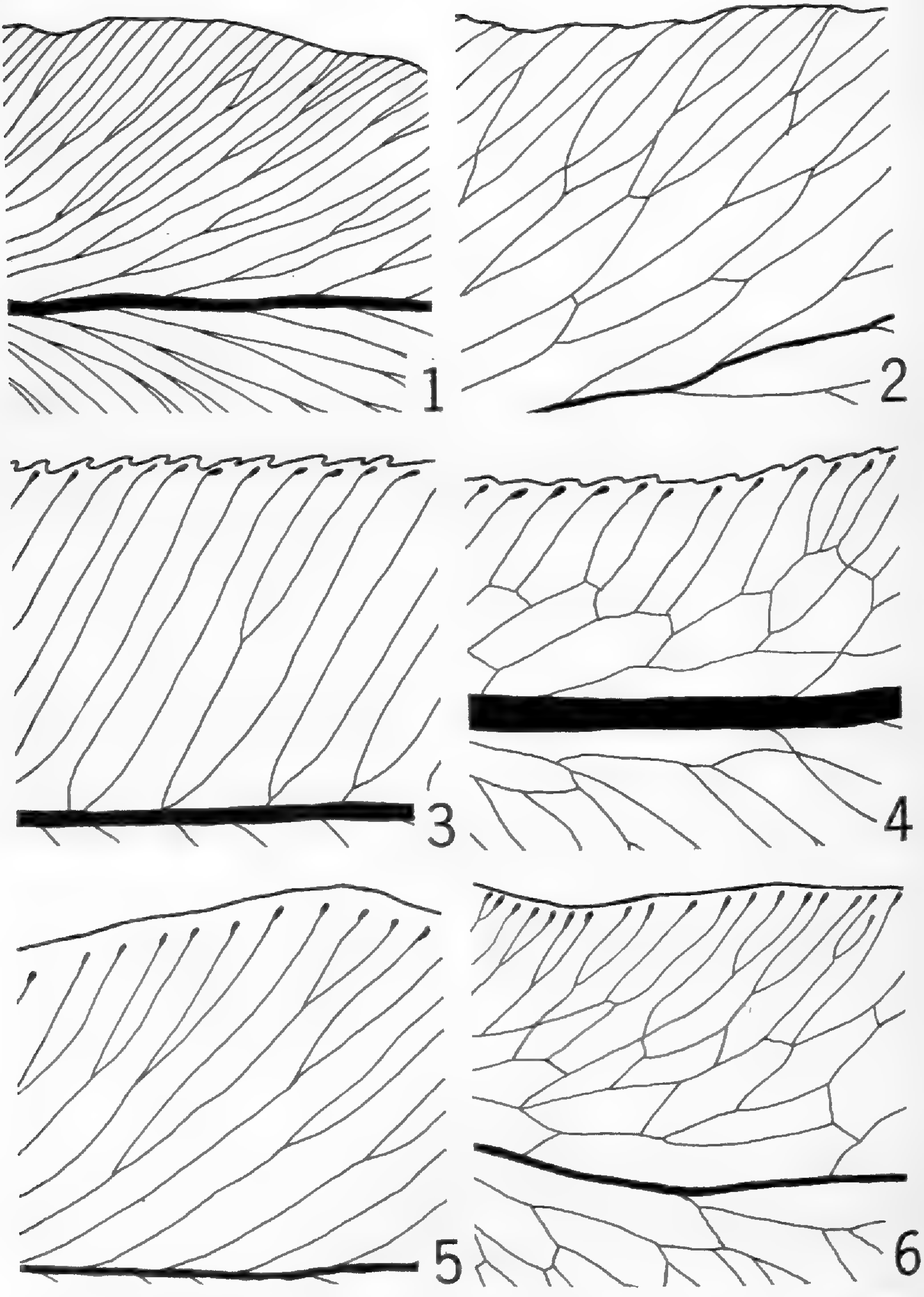
The Taxonomic Position of Coniogramme americana

DAVID B. LELLINGER

Fern genera typically are confined to the Old World or to the New World, or are divided between the two with several to many species in each hemisphere. Only a few genera are confined to one hemisphere except for a single representative in the other. Examples of this peculiar distribution are *Adiantopsis* and *Hemionitis*, which are New World except for *A. linearis* and *H. arifolia*, and *Loxogramme* and *Platycerium*, which are Old World except for *L. mexicana* and *P. andinum*. Therefore, "*Coniogramme americana* Maxon," the only species of that Asiatic–Oceanic–African genus attributed to the New World, aroused my suspicion. A study of this species and its true and presumed relatives has shown that it is a *Gymnopteris*, with one exception a New World genus.

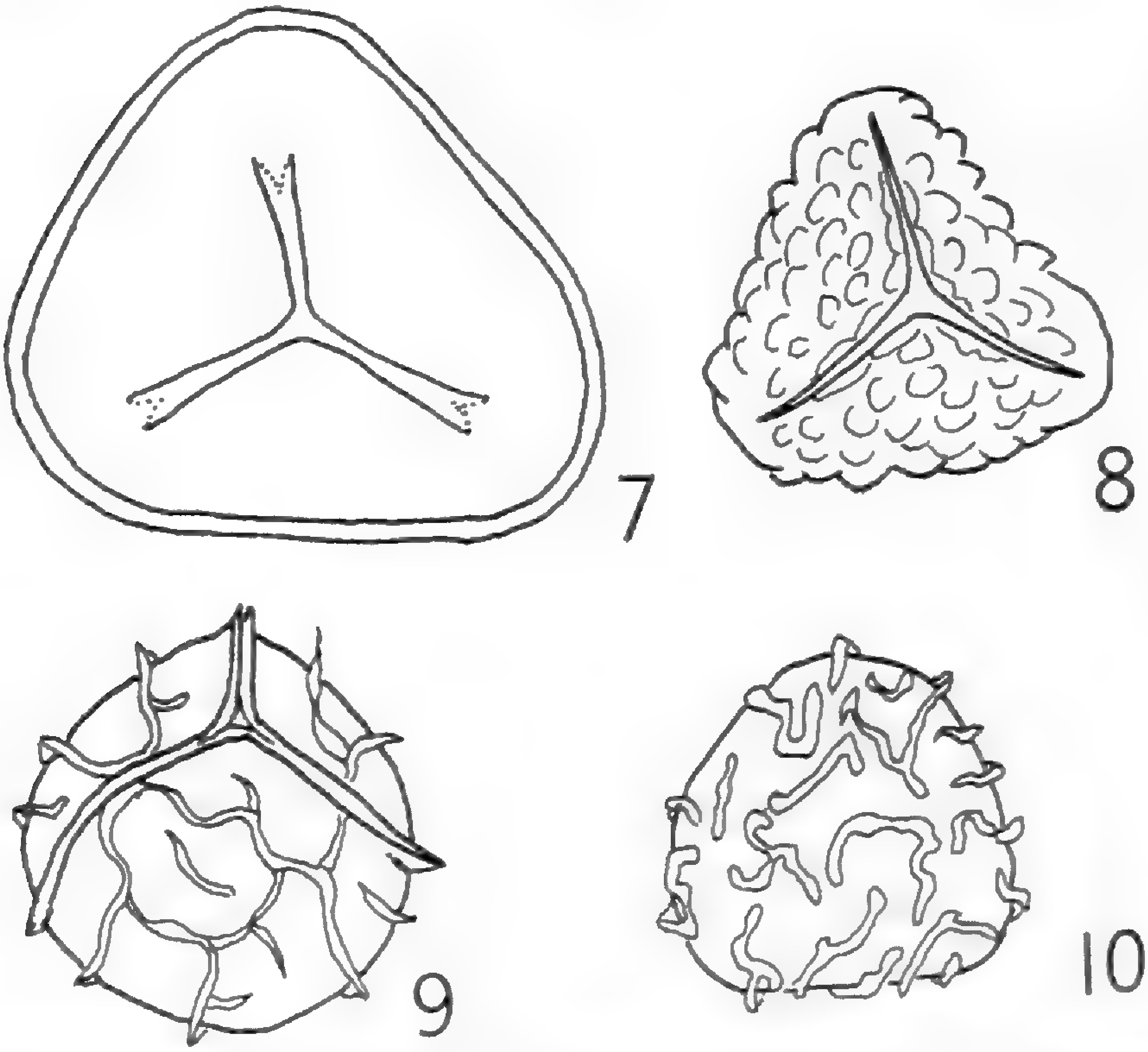
In a lengthy and thoughtful critique of the genus *Gymnogramma* as treated in the "Synopsis Filicum," Underwood (1902, p. 628) correctly transferred *Gymnogramma subcordata* D. C. Eaton ex Davenp. in Rose to *Gymnopteris*. A few years later Maxon (1913, p. 174) transferred this principally Mexican species to *Coniogramme* because the partially areolate venation, the occasional subbipinnate fronds, and the stramineous stipes and rhachises seemed quite similar to *C. japonica* (Thunb.) Diels in Engl. & Prantl. Shortly thereafter Maxon (1916, p. 607) realized that *C. subcordata* (Davenp. in Rose) Maxon was a later homonym of *C. subcordata* Copel. (1910), a Philippine plant, and so he renamed the species *C. americana* Maxon.

The particular kind of areolate venation found in *Gymnopteris subcordata* occurs in many unrelated fern genera. The areoles are costal and subcostal, and are elongate and subpolygonal. Most often this venation occurs in those species of basically free-veined genera that have unusually broad pinnae or segments, presumably as a response to some physiological or structural characteristic. Included veinlets, which are free-ending branchlets within areoles, are never found in these elongate, subpolygonal areoles. The



FREE AND RETICULATE VENATION PATTERNS. FIG. 1. ANEMIA ORGANENSIS. FIG. 2. A. PHYLLITIDIS. FIG. 3. CONIOGRAMME FRAXINEA. FIG. 4. C. JAPONICA VAR. GRACILIS. FIG. 5. GYMNOPTERIS RUFA. FIG. 6. G. SUBCORDATA. ALL × 4.25.

veins are free toward the pinna or segment margins. This derived venation has been found, for example, in *Adiantum* sect. *Hewardia* (*A. olivaceum*), *Anemia phyllitidis*, *Coniogramme* sect. *Dictyogramme* (*C. japonica*), and *Gymnopteris subcordata* (*Plate 5*). The similarity of the areolate venation in these unrelated genera is remarkable and demonstrates clearly the unreliability of this character for associating *G. subcordata* with *Coniogramme*.



SPORES OF CONIOGRAMME AND GYMNOPTERIS. FIG. 7. CONIOGRAMME JAPONICA. FIG. 8. GYMNOPTERIS RUFA. FIG. 9. G. SUBCORDATA. FIG. 10. G. TOMENTOSA. ALL CA. × 820.

Areolate venation without included veinlets is seldom found in groups that have areolate venation with included veinlets, such as *Tectaria*, *Polypodium* sects. *Anaxetum*, *Campyloneurum*, and *Goniophlebium*, and *Thelypteris* sect. *Meniscium*. The latter kind of venation has evolved in parallel only infrequently, and therefore is more useful as a taxonomic character.

Another point of difference between *Coniogramme* and *Gymnopteris* lies in the spores. *Coniogramme japonica*, for instance, has unornamented spores (*Fig. 7*), whereas the species of *Gymnopteris* investigated have variously ornamented spores (*Figs. 8–10*). The jointed hairs of *Gymnopteris* and the narrow, almost linear stipe scales also separate it from *Coniogramme*, which lacks articulate hairs and has broad stipe base scales.

Tryon (1964, pp. 82–84) discusses some of the rather subtle laminar differences between *G. rufa* and *G. tomentosa;* the following key covers all of the New World species of *Gymnopteris* and adds spore and scale characters where applicable.

KEY TO THE NEW WORLD SPECIES OF GYMNOPTERIS

Laminae bipinnate-pinnatifid, broadly deltoid (Brazil). *G. gardneri* (Baker) Underw.

Laminae pinnate to bipinnate, lanceolate, ovate, or nearly linear.

  Venation partially areolate, free only at the margins; stipes and rhachises stramineous; spores conspicuously triradiate and crested (Mexico and Guatemala; *Fig. 9*) . . . . *G. subcordata* (Davenp. in Rose) Underw.

  Venation entirely free; stipes and rhachises castaneous to atropurpureous; spores not both obviously triradiate and crested.

    Rhizome and stipe base scales bicolorous; pinnae all short-stalked, cuneate to subcordate at base; spores triradiate, tuberculate (Greater Antilles, southern Mexico to Peru and Surinam; *Fig. 8*). *G. rufa* (L.) Underw.

    Rhizome and stipe base scales concolorous; pinnae, at least the larger ones, usually long-stalked, truncate to cordate at base; spores not obviously triradiate, crested (Peru to Argentina and Brazil; *Fig. 10*). *G. tomentosa* (Lam.) Underw.

Gymnopteris gardneri is the rarest species of the genus. I have seen only the type specimen (Goyaz, Brazil, *Gardner 4077*, K); perhaps no other collections exist. In its spores and in the morphology, abundance, and position of its hairs and scales it matches *G. tomentosa* exactly. Presumably it is closely related to that species. Tentatively, however, I maintain it as a distinct species because it is consistently bipinnate-pinnatifid (i.e., its pinnae and pinnules are regularly lobed about half way to their axes), a condition which is never found in *G. tomentosa*. Also its stipes are two to three times longer than its rhachises (versus one to two times in *G. tomentosa*), and it has somewhat thinner laminae. Finally, *G. gardneri* has a poorly-developed rosette of pinnate or pinnate-pinnatifid sterile fronds about 0.16–0.20 times as long as the fertile ones. This dimorphism is unknown in the other species of the genus, but on the basis of the single specimen examined, it may not be a constant character.

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New Combinations in Cyathea, Ctenitis, and Asplenium

C. V. MORTON

I have been preparing a new account of the ferns of the Galápagos Islands, Ecuador, in collaboration with Dr. Ira Wiggins. Two of the species and one variety have been found to need new combinations:

CYATHEA **weatherbyana** (Morton) Morton, comb. nov.
Hemitelia weatherbyana Morton, Leafl. West. Bot. **8:** 188. 1957.

This endemic species is the only tree fern that has been found in the Galápagos Islands; it occurs abundantly and in fact is the dominant species at certain elevations on Albemarle, Chatham, Indefatigable, and James Islands. An account of its habitat can be found in John Thomas Howell's "Up under the Equator."[1] In the earlier accounts of the Galápagos ferns this species was wrongly called *Hemitelia multifora* or *H. subcaesia*.

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[1] Sierra Club Bull. **27:** 79–82. 1942.

I now tentatively accept the reduction of *Hemitelia* to *Cyathea*, following Dr. Holttum's demonstration that the indusial character is not reliable, at least so far as the Old World species are concerned. The American species have not been sufficiently investigated. The matter was discussed by Holttum and Sen in their paper "Morphology and Classification of the Tree Ferns,"[2] an important paper that should have been reviewed in the Fern Journal but which never was.

ASPLENIUM FORMOSUM Willd. var. **carolinum** (Maxon) Morton, comb. nov.

Asplenium carolinum Maxon, Contr. U. S. Nat. Herb. **17:** 148. 1913. TYPE: Charles Island, Galápagos Islands, April 8, 1888, *Lee* (US).

This is one of the commonest ferns in the Galápagos Islands being found on almost all the islands of the group. It has generally passed as *A. formosum*, but Maxon considered it specifically different. The plants from the Galápagos are certainly very close to typical *A. formosum*, but do differ consistently in the characters pointed out by Maxon, especially in the less deeply dissected lobes of the pinnae, the usually smaller size, and the presence regularly of sori on both sides of the midrib. Typical *A. formosum* has all the sori on the lower side or occasionally a few on the upper also. However, because of numerous similarities the Galápagos plant seems best regarded as a geographic variety only.

CTENITIS **sloanei** (Poeppig) Morton, comb. nov.

Polypodium sloanei Poeppig ex Spreng. in L. Syst. Nat., ed. 16, **4:** 59. 1827. TYPE: Near Cahoba, Cuba, in dense, humid woods, *Poeppig* (isotype L, Morton photograph 1045).

Polypodium paleaceum Hook. f. Trans. Linn. Soc. London **20:** 166. 1847. TYPE: Charles and James Islands, Galápagos Islands, *Darwin*.

Dryopteris ampla auctt., non Polypodium amplum Humb. & Bonpl.

It is most unfortunate that the application of the name *Ctenitis ampla* (Humb. & Bonpl.) Ching must be changed, for it has been applied since the monograph by Christensen, and even before, to a widely distributed species that occurs in southern Florida, and in

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[2] Phytomorphology **11:** 406–420. 1961.

much of the West Indies and continental tropical America. However, a photograph by Dr. Tryon of the holotype of the basionym, *Polypodium amplum* Humb. & Bonpl. ex Willd., in the Willdenow Herbarium (no. 19722), Berlin, shows that the epithet *amplum* properly belongs to the species called *Dryopteris nemophila* (Kunze) C. Chr. in Christensen's "Monograph of Dryopteris." Christensen himself had some doubt that he was applying the name *ampla* correctly, stating: "Here I follow Mettenius in identifying *Pol. sloanei* Poep. with *P. amplum* Willd., although I have some doubt of that being right . . . It is true that in most characters it agrees very well with pinnae of similar size of *P. sloanei* . . . but in some other characters the type-specimen is scarcely to be distinguished from the form that authors have identified with *Aspidium catocarpum* Kze., which I refer to *D. nemophila* (Kze.) C. Chr. It is therefore an open question, whether *P. amplum* is the same as *P. sloanei* Poep. or *A. catocarpum* Kze.; there remains the possibility that *P. amplum* is a species intermediate between the two others . . ." To me the type specimen of *P. amplum* is exactly the same as *Fendler 204* from Venezuela, which Christensen has identified as *Dryopteris nemophila,* and this in turn does not seem different from Peruvian material that is doubtless the same as the types of *Aspidium nemophilum* Kunze and *Aspidium catocarpum* Kunze, both of which came from Peru. In addition to the characters pointed out by Christensen, it may be mentioned that the pinnae in *C. sloanei* (*D. ampla* sensu C. Chr.) are long-stalked and the pinnules obviously stalked also, whereas the pinnae in the true *C. ampla* (*D. nemophila*) are short-stalked and the pinnules nearly sessile. The most obvious character distinguishing the species is the apices of the pinnules, which are attenuate in *C. sloanei* and obtusish in *C. ampla.* The rhizome scales are somewhat different too, those of *C. sloanei* forming a dense light brown mass and those of *C. ampla* being larger and darker brown, although similar in cellular structure. The veins beneath in *C. sloanei* always bear minute glandular hairs, whereas those of *C. ampla* are at least usually eglandular.

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Taxonomic Significance of Stomatal Patterns in the Ferns

E. LAURENCE THURSTON[1,2]

Stomata have long been an object of study. Stomatal ontogenetic patterns were first investigated a century ago (Hildebrand, 1866; Strasburger, 1866) and more recently by Florin (1931), Stebbins and his associates (Stebbins and Jain, 1960; Stebbins and Khush, 1961; Stebbins and Shaw, 1960), and Pant and associates (Pant, 1965; Pant and Mehra, 1964; Pant and Sirvastava, 1962). Early workers successfully distinguished certain ontogenetic patterns, but only recently have ontogenetic patterns been determined on a large, comparative scale.

The use of taxonomic characters based on mature stomata is not new. The systematic value of stomatal frequency, distribution, and size is questionable, however, because many morphological characteristics vary with differing environmental conditions (Salisbury, 1927; Allsop, 1954). Deductions of ontogenetic patterns from the relationship of the mature subsidiary cells are not always reliable in seed plants (Maheshwari and Vasil, 1961), but they do seem to be reliable in the ferns (Kondo, 1962).

Working only with the ferns, Kondo (1962) classified ontogenetic stomatal patterns by the number of cell divisions necessary to produce the mature stoma and the relative position of the guard cells to the neighboring and subsidiary cells. He described ten patterns occurring in 450 species belonging to 16 families. His survey is a monumental contribution to our knowledge of fern stomata. Unfortunately, Kondo did not discuss the phylogenetic implications of his results thoroughly.

The present study was initiated to determine whether the mature stomatal patterns and their ontogeny might shed light on the relationships of the Dennstaedtiaceae, Dicksoniaceae, Pteridaceae, and Cyatheaceae. These families have been treated in

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[1] I would like to thank Dr. John T. Mickel, who suggested the problem and helped in the preparation of this manuscript.

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various ways by different pteridologists. Most commonly the Dicksoniaceae, Dennstaedtiaceae, and Pteridaceae have been placed together, primarily on the basis of their marginal sorus position, with the Cyatheaceae being placed in a separate line of evolution (Bower, 1926; Ching, 1940; Copeland, 1947; Holttum, 1946, 1949). Pichi-Sermolli (1958) and Mehra (1961) placed the Dennstaedtiaceae and Dicksoniaceae close to one another and put the other two families on separate, distant lines of evolution. Dickason (1946) went one step farther, placing all four on separate lines within the Filicales.

The material for this investigation came largely from herbarium specimens obtained from Iowa State University (ISC), the University of Michigan (MICH), the Missouri Botanical Garden (MO), the United States National Herbarium (US), and the private herbarium of Dr. John T. Mickel. It was supplemented with living material from the greenhouses of the Department of Botany and Plant Pathology at Iowa State University. Seventy specimens representing 26 genera and 61 species were examined (*Table I*).

Frond segments were cleared in 5% aqueous sodium hydroxide for several days, with final clearing in a 20% solution of Clorox. The specimens were stained with tannic acid-ferric chloride, as described by Foster (1934) modified to use a 5% solution of tannic acid. The stained segments were mounted in Diaphane or Piccolyte.

It was necessary to examine living material to determine the reliability of using dried material to determine stomatal ontogeny. Young pinnules from various greenhouse ferns (*Lygodium, Pteris, Davallia,* and *Platycerium*) were fixed in Farmer's solution, mounted in acetocarmine (Sass, 1958), diluted to half strength with 45% glacial acetic acid and heated almost to boiling for approximately 30 seconds. The coverslips were sealed with a 1:1 paraffin-beeswax mixture and stored in a refrigerator at 5° C prior to examination (Stebbins and Khush, 1961). An alternate method was later employed which required less time and provided better results. The fixed material was stained with iron hematoxylin (Sass, 1958), but the time in hematoxylin and mordant was reduced from four hours to one half hour. The stained material was then dehydrated and either mounted in clove oil or mounted permanently in Piccolyte. In all cases, the stomatal ontogeny determined from the young living material was identical to that determined from dried mature specimens.

TABLE I. STOMATAL PATTERNS IN VARIOUS FERNS

Name	*Stomata Types*
DENNSTAEDTIACEAE	
Dennstaedtia arborescens (Willd.) Ekman ex Maxon *Smith 2218*[1]	3b
D. bipinnata (Cav.) Maxon *Smith 2431*	3b
D. cicutaria (Swartz) Moore *Mickel 621*	2b
D. cicutaria (Swartz) Moore *Smith 1070*	2b, 3b
D. cuneata (J. Sm.) Moore *Elmer 17982* (MO)	2b
D. distenta (Kunze) Moore *Mickel 1175*	3b
D. distenta (Kunze) Moore *Mickel 1281*	2b, 3b
D. globulifera (Poir.) Hieron. *Mickel 589*, *Smith 1118*	2b, 3b
D. hirsuta Mett. *Togasi 1637* (MO)	2b, 3b
Hypolepis nigrescens Hook. *Mickel 1511*	2b
H. nigrescens Hook. *Mickel 908*	2b, 3b
H. repens (L.) Presl *Purpus 6057* (MO)	2b
H. tenuifolia (Forst.) Bernh. *Elmer 16449* (MO)	2b
H. viscosa (Karst.) Mett. *Smith 1022*	2b, 3b
H. sp. *Levine 1466* (MO)	2a, 2b
H. sp. *Smith 2217*	2b
Leptolepia novae-zelandiae (Col.) Kuhn *Helms* (US)	2b
Microlepia marginata (Houtt.) C. Chr. *Charette 1492* (MO)	3a, 3b
M. proxima (Blume) Presl *McClure 9480* (MO)	3b
Ormoloma imrayanum (Hook.) Maxon *Duss 4176* (US)	3b
O. standleyi Maxon *Standley & Valerio 51434* (US)	3b
Paesia anfractuosa (Christ) C. Chr. *Wercklé* in *1901*	2b
P. divaricatissima (Dry.) Copel. *Grant 4177*	2b
P. radula (Bak.) C. Chr. *Bartlett 7999*	2b
Saccoloma inaequale (Kunze) Mett. *Mickel 974*	3a, 3b
S. minus (Hook.) C. Chr. *Degener 14648* (MO)	2a, 2b
S. minus (Hook.) C. Chr. *Gräffe* (US), *Setchell & Parks 15076* (US)	2b
S. moluccanum (Blume) Mett. *Wenzel 646* (MO)	3a, 3b

Name	*Stomata Types*
DICKSONIACEAE	
Cibotium regale Linden *Yuncker, Dawson & Youse 5851* (MO)	X
C. schiedei Schlecht. & Cham. *Brandegee 1976* (MO)	X
Culcita coniifolia (Hook.) Maxon *Mickel 917*	1
C. macrocarpa Presl. *Trelease 1141* (MO)	2a, 2b
Cystodium sorbifolium (J. E. Sm.) J. Sm. *Wagner 3513* (US), *Hose* (US)	2a, 2b
Dicksonia brackenridgei Mett. *McKee 2980* (US)	2a
D. gigantea Karst. *Killip 5207* (MO)	2b
D. karsteniana (Kl.) Moore *Steyermark* (US)	2a
Thyrsopteris elegans Kunze *Weatherby 17335* (MO)	1
CYATHEACEAE	
Alsophila corcovadensis (Raddi) C. Chr. *Mexia 4634* (MICH)	3a
Cyathea fulva Fée *Mickel 919*	3b
C. jurgensenii Fourn. *Mickel 1081*	3b
C. mexicana Schlecht. & Cham. *Mickel 1089*	2b
C. moluccana R. Br. ex Desv. *Cuming 378* (MICH)	3b
C. podophylla (Hook.) Copel. *Kao 930* (MICH)	2b
Hemitelia apiculata Hook. *Mickel 994*	3b
H. capensis (L. fil.) Kaulf. *Brade 16527* (MO)	3b
H. grandifolia (Willd.) Spreng. *Buchtien 5224* (MO)	3a
Lophosoria quadripinnata (Gmel.) C. Chr. *Mickel 901*	X
Metaxya rostrata (H. B. K.) Presl *Erlanson 62* (US), *Fendler 47*, *Pittier 8579* (US), *Welch 19609* (MO)	X
PTERIDACEAE	
Histiopteris incisa (Thunb.) J. Sm. *Mickel 1143*	2b
Anisosorus hirsutus (L.) Kuhn *Brenckle 95* (US), *Harris 7121* (US), *Standley 52929* (US)	2b
Lonchitis lindeniana var. decomposita Christ *Williams & Allen 16477* (US)	2b
Neurocallis praestantissima Fée *L'Herminier 1862* (US), *Pittier 14040* (US)	3a
Pteridium aquilinum var. arachnoideum (Kaulf.) Hert. *Mickel 1066*	2a, 2b
P. aquilinum var. feei (Schaffn. & Fée) Maxon ex Yuncker *Mickel 1182*	2a, 2b
Pteris altissima Poir. *Smith 2429*	3b
P. mexicana (Fée) Fourn. *Mickel 582*	3a
P. podophylla Swartz *Smith 1080*	3a, 3b

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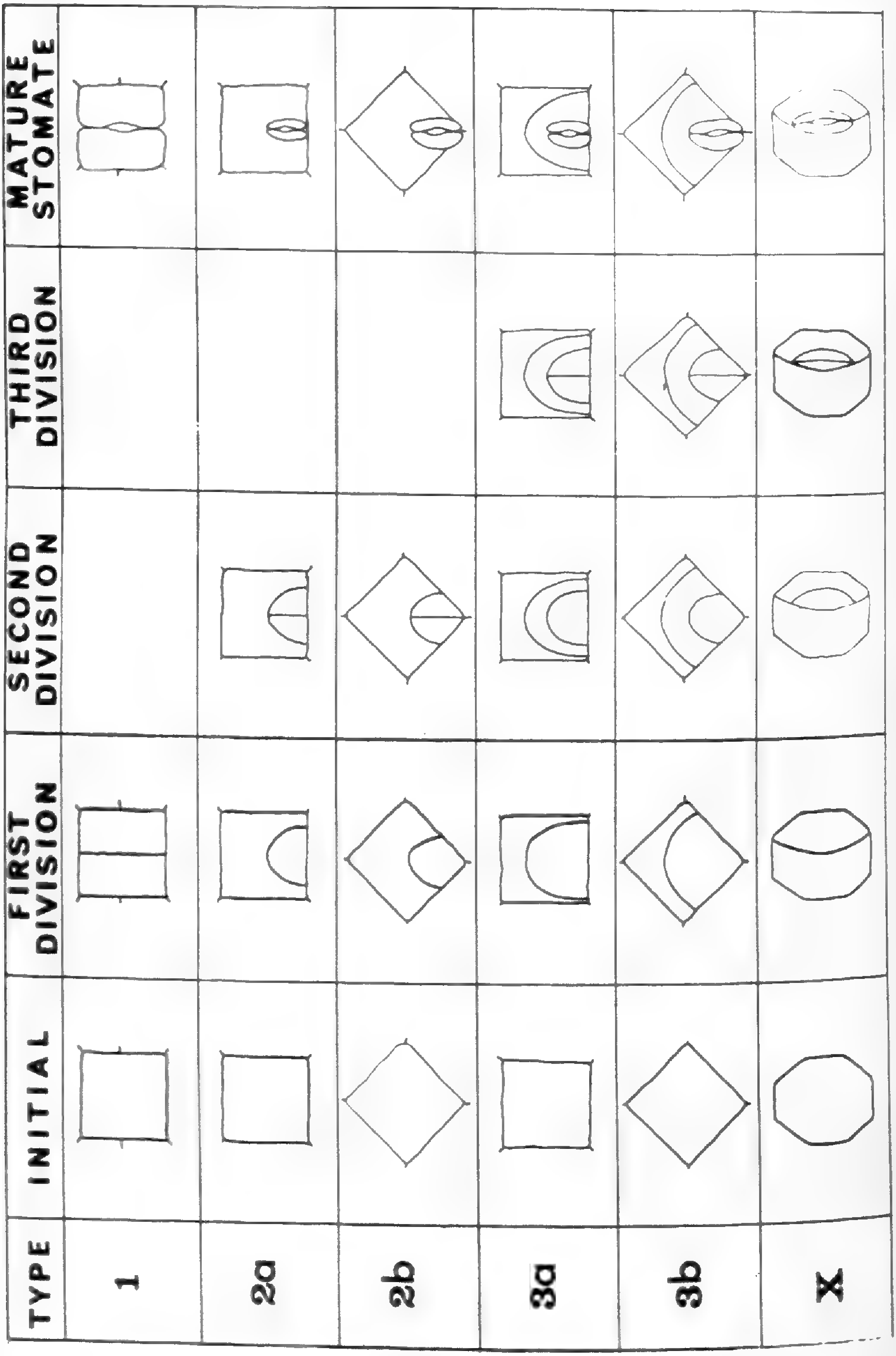
[1] Specimens without indication of herbarium are in ISC.



ONTOGENETIC PATTERN OF FERN STOMATAL DEVELOPMENT

All the illustrations of stomatal patterns were taken from the abaxial surface of the pinnae, and in most cases only those patterns which did not occur close to the vein or leaf margin were recorded. In some cases, however, it was necessary to use stomata near the veins or the margin, although frequently they are distorted. The illustrations were made with the aid of a Zeiss drawing apparatus.

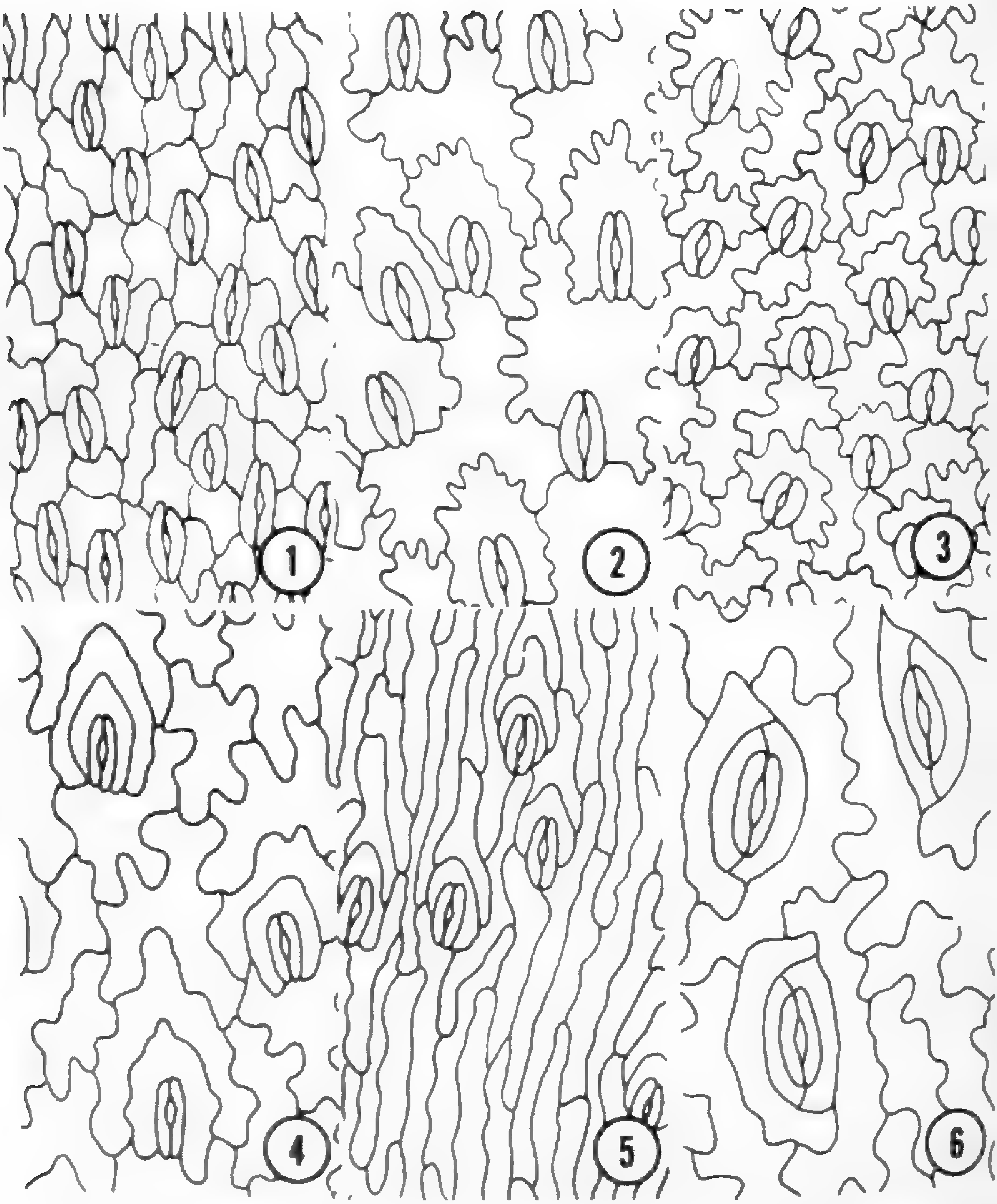
Four basic stomatal patterns exist in the four families investigated. These are classified on the basis of the number and orientation of cell divisions (*Plate 1*) necessary to produce a mature stomatal complex of stoma and surrounding subsidiary cells (Kondo, 1962).

The simplest pattern is the result of a single division of the stoma mother cell and is designated as the Type 1 pattern (*Fig. 1*), possessing no subsidiary cells. The remaining patterns all involve more than one division of the stoma mother cell.

In Type 2 two cell divisions occur; the first is arcuate to the proximal wall of the stoma mother cell and the second is perpendicular to the same wall of the stoma mother cell. This pattern is subdivided into Types 2a (*Fig. 2*) and 2b (*Fig. 3*) on the basis of the orientation of the guard cells relative to the subsidiary cell. In Type 2a the guard cells contact one lateral wall of the subsidiary cell; in 2b the guard cells are in contact with two lateral walls of the subsidiary cell.

In Type 3 three cell divisions occur. In terms of cell alignment, this pattern is basically similar to Type 2, with an additional cell division of the stoma mother cell. The first two divisions are similarly oriented, initiating two subsidiary cells, whereas the third produces the two guard cells. This pattern also is divided into 3a (*Fig. 4*) and 3b (*Fig. 5*) by the same criterion as in Type 2.

The fourth pattern, Type X (*Fig. 6*), also requires three cell divisions, but in this case all three of the divisions are parallel to one another and to the long axis of the stoma mother cell. Kondo (1962) reports that in *Cheiropleuria* (Polypodiaceae) and *Cibotium* (Dicksoniaceae) a fourth division takes place to form the mature stoma. The patterns found in the materials studied are reported in *Table I*.



MATURE STOMATAL PATTERNS. FIG. 1. THYRSOPTERIS ELEGANS (Type 1); FIG. 2. CYSTODIUM SORBIFOLIUM (Type 2a); FIG. 3. HYPOLEPIS SP. (Type 2b); FIG. 4. MICROLEPIA MARGINATA (Type 3a); FIG. 5. DENNSTAEDTIA SP. (Type 3b); FIG. 6. METAXYA ROSTRATA (Type X).

In order to assess the results of this survey in perspective, my findings were combined with those of Kondo (1962) and superimposed on the phylogenetic scheme of Bower (1926) (see *Plate 2*). The numbers appearing on this scheme represent the stomatal patterns found in each group.

Type 1 occurs in the most primitive fern families (Ophioglossaceae, Marattiaceae, Osmundaceae) and in the genera *Thyrsopteris* and *Culcita*, which are considered primitive members of the Dicksoniaceae. The Type 1 pattern is also found in the fern allies (Pant and Mehra, 1963), with the exception of *Equisetum* (Hauke, 1957) and in the bryophytes (Payton and Pearce, 1957).

The Type 2 pattern is well distributed in fern families which are considered to occupy intermediate phylogenetic positions, such as the Gleicheniaceae, Matoniaceae, Schizaeaceae, and several more advanced groups. The Type 3 pattern is found only in fern families which are considered to be relatively advanced phylogenetically. Type 2 and Type 3 are found together in the Cyatheaceae, Dennstaedtiaceae, and Pteridaceae, but Type 3 predominates in such specialized groups as the Aspidiaceae and Polypodiaceae. Thus, the overall trend is from Type 1 to Type 2 to Type 3; in other words, there has been an increasing number of cell divisions required to produce the stomatal complex. This trend is generally seen, but exceptions exist in the illustrated scheme. This suggests that the relationship of these families may be misunderstood. The taxonomic importance of stomatal pattern subtypes "a" and "b" is difficult to assess at present. They often lend themselves to subjective determination and are commonly variable with frequent intermediates. Both subtypes occur in three of the four families investigated in this study and in several families studied by Kondo (1962). On the other hand, several fern groups have only one subtype present. The Schizaeaceae, Gleicheniaceae, and Blechnaceae have all or nearly all subtype "a." The Plagiogyriaceae, Aspidiaceae, and Polypodiaceae are characterized exclusively by subtype "b." More detailed studies on this problem are needed.

The X pattern is most peculiar and does not easily fit into the

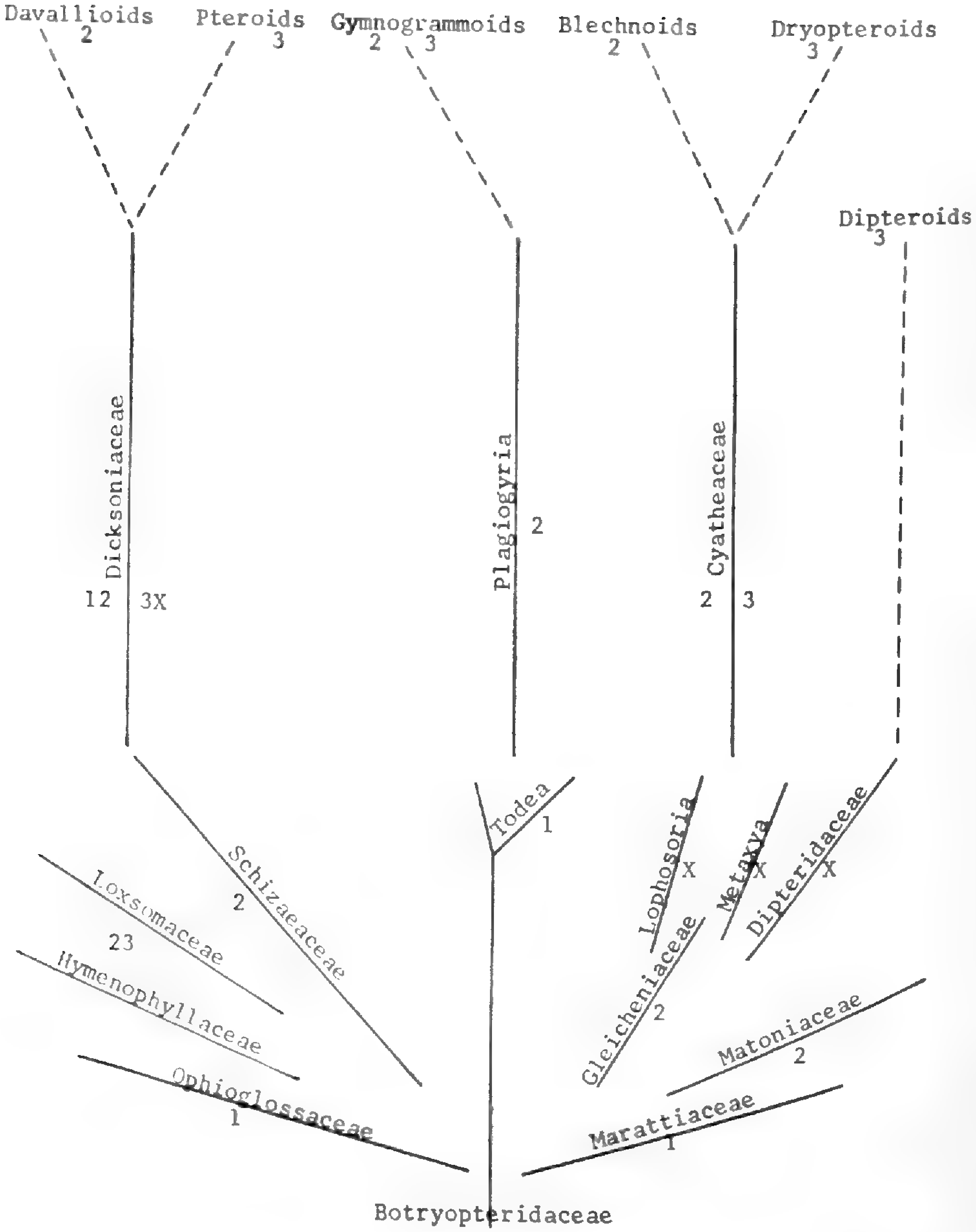


DIAGRAM OF THE FERN CLASSIFICATION OUTLINED BY BOWER (1926). THE NUMBERS AND LETTERS REPRESENT STOMATAL PATTERNS.

general trend. It differs from the other stomatal patterns in that the plane of the first two cell divisions is nearly parallel to that of the guard cells. In the Type 2 and Type 3 patterns the plane of the division or divisions is arcuate to the proximal wall of the stoma mother cell.

The X pattern occurs in *Dipteris*, *Cheiropleuria*, *Cibotium*, *Dicksonia*, *Metaxya* and *Lophosoria*. All of these genera occupy primitive positions within their respective families of phyletic lines. *Metaxya* and *Lophosoria* generally have been considered to be primitive members of the cyatheoid ferns. Bower (1926) goes so far as to construct a separate family, the Protocyatheaceae, for them. *Dicksonia* and *Cibotium* occupy a relatively primitive position in the Dicksoniaceae, whereas *Dipteris* and *Cheiropleuria* (Kondo, 1962) are considered primitive members of the polypodioid line. The occurrence of the X pattern in three different groups might be the result of parallel evolution. On the other hand, the fact that they occur in the primitive members of the three groups more strongly suggests some sort of relationship between these groups. A dicksonioid-cyatheoid relationship has been suggested by Holttum and Sen (1962), who have also pointed out a possible closer relationship of *Lophosoria* and *Metaxya* to the dicksonioid ferns than to the cyatheoid line (Roy and Holttum, 1965). Further examination of other characters may possibly indicate a relationship between all three groups possessing the X pattern (dicksonioids, protocyatheoids, and dipterids).

Regarding the relationship of the Dennstaedtiaceae, Dicksoniaceae, Cyatheaceae and Pteridaceae, stomatal patterns support phylogenetic ideas that they are either closely related or at least are of roughly the same level of advancement. The Dicksoniaceae appear to be less specialized than the other three families in having representatives with the simplest pattern (Type 1) and no representatives with the most complex pattern (Type 3). The Cyatheaceae with no subtype "a" pattern may be more specialized than the other families.

Although a phylogenetic scheme should not be based entirely on a single character, such as stomatal ontogenetic patterns, these patterns seem to be taxonomically significant. Linked with other characters, further studies of stomatal patterns should contribute significantly to our understanding of relationships within the ferns.

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Shorter Notes

PROPAGATION OF MOTHER FERNS, ASPLENIUM DAUCIFOLIUM.—Although the usual type of Mother Fern, *Asplenium bulbiferum,* is not difficult to grow from the bulblets, the more finely cut *Asplenium daucifolium* (*A. viviparum*) is much more difficult. I have had a plant of *A. daucifolium* for a number of years, and it is continuously covered with plantlets. I tried rooting whole fronds, pinnae, and individual plantlets to no avail. Later, I placed the pot in which the mother plant is growing under a tree fern, *Alsophila australis.* I noticed that the plantlets that fell off were remaining green for months. In the spring I tried potting a few, for I expected that the two larger ones that had tiny but true bipinnate fronds about one and a half inches long would have a good root system and the smaller ones with only four or five entire fronds would have some roots. The ones with the bipinnate fronds did have a few roots and they grew rapidly. Some of the others had more than one short root or what looked like a root, which was often caught among the tree fern roots, and others had no root at all. I potted a dozen of those without roots, and I think that five survived and produced true fronds. I potted them in Mexican tree fern fiber plus a little sphagnum. However, after six months they were still under two inches high. Apparently, these plantlets require more patience than sporelings. They need lots of humidity and moisture, but will not stand conventional potting. Within ten days or two weeks I lost all those that I tried to cover or hold down. The ones that grew were just laid on the medium and sprayed, with a piece or two of the fern fiber over the edge of a frond to hold the plantlet in place a bit.

I should be most interested to hear how others may have achieved success.—MRS. WILLIAM C. KNOX, *649 Isle of Palms, Fort Lauderdale, Florida 33301.*

POLYPODIUM VIRGINIANUM NOT RESTRICTED TO ROCKY HABITATS—In a recent article (THIS JOURNAL **58:** 153–154. 1968) F. R. Fosberg, reporting an occurrence of *Polypodium vulgare* L. on Long Island, states that he has not seen the American *Polypodium virginianum* L. on any substratum except rock, and that the U. S. National Museum collections citing habitats were all from rocks.

Although this species is more common in those parts of Michigan where rock outcrops occur, especially the Upper Peninsula, it is not confined to such habitats. In the sand dunes along the eastern shore of Lake Michigan flourishing colonies sometimes occur on wooded dune slopes. In localities I have seen the situation could be described as open shade, usually on steep slopes, under either hemlocks (*Tsuga*), or various deciduous tree species, or a mixture. *Dryopteris marginalis* is a frequent associate.

The herbarium of Cranbrook Institute of Science (BLH) contains eleven collections from the dune region, from Berrien County to Leelanau County, a distance of about 200 miles. Nine of these have habitat data which specifically mentions either dunes or sandy soil. I have examined these collections under the microscope and all were found to have the glandular paraphyses typical of *P. virginianum.* In addition to these, the herbarium contains collections from a sandy slope in Livingston County and from a gravelly substratum in Jackson County, both in southeastern Michigan. In a number of cases the labels specify the location as being at the base of trees.

Another habitat in the Great Lakes region is on old stumps or rotting logs. Examples, as given on herbarium labels are: "Moist woods, black muck soil; mountain maple, white cedar, yellow birch, hemlock. Several plants on rotting log. No other plants in area," Benzie County, *Appelhof 28;* "Frequent on rotten mossy logs, mixed woods . . ." Beaver Island, Charlevoix County, *Voss 6868;* and "On a stump under balsam," Great Duck Island, Ontario, *Grassl 1662.* Each of these collections includes fertile fronds from 9 to 12 inches long. Five collections from such habitats are in the herbarium, and examination has shown that all are correctly identified as *P. virginianum.*

Some other fern species normally considered plants of rocky habitats, e.g., *Asplenium viride, Camptosorus rhizophyllus, Polystichum braunii,* and *P. lonchitis,* have been reported as growing on rotting logs or sandy soil in a dune area on South Manitou Island, Leelanau County (Thompson, Amer. Fern J. **52:** 157–159. 1962). Of these species, the last named has now been found on a wooden dune slope on the mainland in Leelanau County (*Thompson L-2199,* BLH). The presence of all these species, as well as of *Polypodium virginianum,* on rock outcrops in a number of localities across Lake Michigan, but within a radius of 150 miles to the north or northwest in Wisconsin and Upper Michigan, suggests that the dune area stations have originated from wind borne spores deposited in ecologically suitable micro-habitats.—Dale J. Hagenah, Cranbrook Institute of Science, Bloomfield Hills, Michigan 48013.

GROWING BULBLETS OF ASPLENIUM BULBIFERUM AND A. DAUCIFOLIUM.—In the Fern Journal (**53**: 81. 1963) Mr. Morton indicated that it is difficult to grow the bulblets of the mother-ferns, *Asplenium bulbiferum* and *A. daucifolium.* My experience is somewhat to the contrary. My first acquaintance with *Asplenium bulbiferum* was in 1960, when Henry Potter of West Rutland, Vermont, gave me four budding pinnae. I understand that the fern had been brought into the United States many years ago from the Azores by a sea captain.

I immediately planted the four specimens, just partially covering the mother pinnae but keeping the plantlets in the clear. The growing medium was woodland mulch taken from a hemlock-maple forest. Three of the four specimens grew. They were re-potted in a topsoil-humus-sand mixture in pots standing in damp vermiculite. For lighting they received 14 hours daily illumination from two 40-watt fluorescent tubes of the daylight type. I now use two 40-watt Gro-lux tubes daily for 18 hours. During the winter months the plants are stored in the basement, which has a daily temperature range from 60° to 68°, but during the summer they have been subjected to temperatures ranging from 46° to 96°.

Since my first experience I have grown many plants by starting the bulblets directly in damp vermiculite. I do not have a record of the mortality of these, but I feel amply rewarded with the results. My most recent test has shown that eight out of ten bulblets produce plants ready for potting in eight months when grown in a humidity chamber.

My first attempts to grow *Asplenium daucifolium* (*A. viviparum*) under normal room conditions were futile. At present I am growing the bulblets in a humidity chamber and feel that the yield will be nearly 100 per cent.—F. GORDON FOSTER, *P. O. Box 136, Sparta, New Jersey 07871.*

Notes and News

THE COUNCIL ON BIOLOGICAL SCIENCE INFORMATION (COBSI) will hold a symposium on August 20, 1969, at the AIBS meeting in Burlington, Vermont. Any Fern Society member who is interested in this topic and who plans to attend this symposium is invited to submit an informal report to the President of the Fern Society.—D.B.L.

ANSWERS TO QUESTIONS: At the request of the Council, C. V. Morton (U. S. National Museum, Washington, D. C. 20560) has stated his willingness to answer questions regarding ferns. If the questions and answers are of sufficient general interest, they may be published in the JOURNAL.

FERN SOCIETY members and all others who will be in Seattle at the time of the XI Botanical Congress and who wish to attend the Society's informal luncheon are urged to make their reservations now. See page 27 of the March JOURNAL.

Recent Fern Literature

FLORA OF ALASKA AND NEIGHBORING TERRITORIES, A MANUAL OF THE VASCULAR PLANTS, by Eric Hultén. Stanford University Press, Stanford, California, 1968. 1008 pp. $35.00.—This review is intended to treat only the pteridophyte section, found on pp. 24–59, of this fine manual, but much of what can be said applies to the entire work. This is a manual in the broadest sense. The reader is presented with keys to all taxa treated; pertinent, though not complete, listing of nomenclatural synonyms; a discussion of each taxon including a description with habitat, range, type locality in broad terms; occasionally economic uses; and often a discussion of taxonomic problems within the taxon. The descriptions are only two to a page and are accompanied by very adequate line drawings of each taxon placed in the margin which, although it results in a larger book than necessary, makes reference to the plates most convenient and leaves considerable marginal space for notes. Two outline maps also accompany each taxon, one of the range within the area treated and one of its world-wide distribution. The maps are small; readers not accustomed to using polar projection maps will find the world-wide map relatively difficult to use and imprecise, but nevertheless better than a mere listing of countries or regions. The regional map is on a more adequate scale and includes not only an outline of the range, but also dots to indicate the approximate locality of the known collections. The region includes Alaska, the "neighboring territories" of the Yukon, a small part of the Northwest Territories of Canada, and the Chukchi Peninsula (that part of the Soviet Union most adjacent to Alaska and important to the author's interest in trans-Bering Strait plant relationships). Lists of the authors of plant names included in the flora, plus all the persons for whom taxa have been named, with a concise bibliographic note, add to the general information and value of the manual.

An introductory section outlines the high points of the regional climate, geology, botanical collecting, history, and in particular a summary of the current data supporting the geological history and fluctuations of Beringia—the land bridge between the Soviet Union and Alaska. This whole section is very readable and informative; the precision of dating the opening and closing of the land bridge, which happened four times in four thousand years, staggers the imagination.

The nomenclature of the pteridophyte section is modern and resembles the "Flora Europaea," with numerous changes from his previous Alaskan and Aleutian floras. *Lycopodium* has not been subdivided into *Huperzia, Lycopodium,* and *Diphasium,* as is the current European trend, although the latter may well be a more reasonable treatment. In keeping with the author's interest in geographical relationships, there is a greater tendency to divide at the subspecies rather than the species level. Both the "subspecies" and "variety" category are used, and in the introduction the author discusses his application of the term "subspecies" to morphological variants with a geographical basis. He also apologizes for the necessary nomenclatural changes. He indicates that his use "of varieties and forms is quite conventional, and no more need be said of them." This is perhaps true in the European sense, but I think there is less agreement among North American workers. Whereas some would place "subspecies" above "variety," others would make than essentially equivalent,, and one might wish for a more extensive statement as to his application of the latter term. The several nomenclatural changes in this volume were published separately and previously in Arkiv för Bot., II, **7**(1): 1–147. 1967, and in Madroño **19**(6): 223. 1968. There are unfamiliar names like *Athyrium distentifolium* Tausch (*A. alpestre* (Hoppe) Ryl.) and *Thelypteris limbosperma* (All.) Fuchs (*T. oreopteris*). Whereas much of the pertinent synonymy has been cited, the widely used but possibly illegitimate *Gymnocarpium* has been used with no mention of the alternative, *Carpogymnia* Löve and Löve. One might hope that the former, well-known name might prevail (through conservation if necessary), but the latter is available; the nomenclatural details have been discussed by Morton (Amer. Fern J. **55**: 86. 1965). *Lycopodium selago* var. *patens* is cited in Hultén's "Flora of the Aleutian Islands," but is not mentioned with any of the three varieties of *L. selago* in the present treatment. *Lycopodium obscurum* is treated here as var. *dendroideum;* there is some justification for even higher rank than this. The introduction indicates that the generic order follows Christensen in Verdoorn's "Manual of Pteridology," but in several cases it more nearly, although not completely, follows "Flora Europaea." The treatment of the families also follows that of "Flora Europaea." With a elatively small fern flora, the family key is short and appears workable. Little reference is made to the families in the text, so one's preference is of little consequence. There are several systems of pteridophyte family classification available today, none of which is altogether satisfactory. There is current interest in this country toward a major pteridophyte revision for the Flora North America project, and one would hope that a group effort on the problem might produce a better family alignment. A few minor errors were found. Adiantaceae is misspelled in the family key, *Thelypteris phegopteris* is misspelled in the species key, and Equisetaceae, *Equisetum* and *Polystichum* appear on the page following that indicated in the index.

No amount of minor editorial details or differences in taxonomic interpretation can detract, however, from the fine work done by a scholar intimately acquainted with his subject. The fact that the book is large, heavy, and expensive—and therefore perhaps of more use in the laboratory and the library than in the field—detracts not at all from the craftsmanship by the publisher and the wealth of information by the author. —A. MURRAY EVANS, *Dept. of Botany, University of Tennessee, Knoxville, Tenn. 37916.*

HARDY FERNS, by Reginald Kaye. Faber & Faber, Ltd., 24 Russell Square, London W.C. 1, England. 1968. 203 pp. $8.00 postpaid. —This new book on growing ferns will be welcomed by American gardeners, for although it is written with English conditions especially in mind, most of the comments are equally applicable in the United States. In the nineteenth century ferns were much grown in England and special attention was given to the many varieties of native ferns, of which more than a thousand were in cultivation. Most of these were gradually lost by the decline of large estates and by two world wars, but there is interest again in getting these varieties back in cultivation. Some were doubtless sports that never will appear again, but others will take their place. Some of these sports were found in the wild, but many were raised by selection from spores and kept in cultivation by vegetative propagation. The treatment in this book includes not only these varieties but also all the species that are currently in cultivation outdoors in England. There are also chapters on growing ferns in houses, in rock gardens, in Wardian cases and bottles, and in the city. Most ferns do not like the polluted air of cities, but some seem to be able to survive, even in dark areaways. Mr. Kaye indicates those that are most suitable for city conditions. One thing that strikes an American as odd is the recommendation of *Onoclea*, which in the eastern United States is regarded as a slightly obnoxious weed, but perhaps it is not weedy in England. I have a little doubt that Hart's-tongue is a suitable house plant in the United States; it probably does better in England because

English houses tend to be cooler than ours. Mr. Kaye gives rather detailed instructions as to planting. He righlty stresses the preparation of the soil and the provision of adequate drainage. The only error I noted is the use of the name *Matteuccia germanica* rather than the correct *M. struthiopteris* for the Ostrich Fern. —C.V.M.

ESSAYS ON FORM IN PLANTS, by C. W. Wardlaw, xiv + 399 pp. illustr., Barnes & Noble, New York, 1968. $8.75.—In this volume Professor Wardlaw has compiled and reprinted essentially unchanged a series of thirty essays, articles, addresses, and book reviews originally published in various journals (principally Nature and The New Phytologist) over the years 1944–1966. The selections are a concentration of Wardlaw's thought and work, which has been concerned with plant morphogenesis. Eight of the essays largely or entirely concern fern morphogenesis; the apices of several common north temperate fern species have supplied him with much of his experimental material. The introduction to the essays consists of a delightfully spirited account of the history of plant morphogenesis from the time of Wolff (1759) to the present. Fortunately, the development of Wardlaw's own researches and philosophy is included, which yields much insight into the author's productive research career and the difficulties he overcame in choosing its direction. Wardlaw's lucid style makes this collection of essays both convenient and pleasurable for all who are interested in morphogenesis in the pteridophytes and flowering plants.—D.B.L.

FUNGI ON SELAGINELLA, by M. L. Farr and H. T. Horner. Nova Hedwigia **15:** 239–283, *t. 30–37*. 1968.—In a study of the arrangement of microspores and megaspores in *Selaginella*, Profs. H. T. Horner, Jr. and H. J. Arnott cleared many specimens of *Selaginella* subg. *Selaginella* from the United States (see Bot. Gaz. **124:** 371–383. 1963 for an account of this work). The clearing revealed the presence of many fungi that are not usually obvious on casual viewing. These occur mostly on stems and on moribund or dead vegetative leaves, but some are on sporophylls. The fungi occurring on *Selaginella* have not been studied intensively previously, although some 26 species have been noted. The present study adds 29 additional species, including two new genera and 16 new species. The two new genera, both placed in the Fungi Imperfecti, are *Crucellisporium selaginellae*, found on *Selaginella rupestris* in North Carolina collected by Dr. Wherry, and *Phaeodochium myrothecioides*, the host being *S. lepidophylla* in western Texas, collected by Ferriss. A number of other fungi are present on *Selaginella* but unidentifiable due to lack of spores. It is interesting that except for three ubiquitous species none of the species occurring on *Selaginella* have been found on *Lycopodium*, which has its own fungal flora of at least 40 species. C.V.M.

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American Fern Journal

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The Fern Collections in Some European Herbaria, IV

C. V. MORTON

THE ROYAL BOTANIC GARDENS, KEW

The world-famous Royal Botanic Gardens, Kew, are located on the south bank of the River Thames to the southwest of and adjacent to Greater London. They are so close that they can be reached by the Underground or by city busses. They are a favorite place for garden-lovers of all nationalities, and on good spring and summer days they are filled with people of all ages enjoying the broad expanses of formal gardens and pools, the beautiful flowers of the herbaceous and rock gardens, the stately trees of the aboretum, and the large greenhouses crowded with ornamental plants from more tropical climates. Two or three hundred years ago this land was in the "country," and a part of royal estates. The plural "Gardens" is used in the name for historical reasons, since the present gardens are composed of two royal gardens that in past times were adjacent but separate. The original gardens were primarily for ornamental plants and for recreation, and their transformation into true "botanical gardens" has been a slow development over more than two hundred years.

Although I appreciate and enjoy the living plants like any other plant-lover, my special interest is in the large herbarium that has grown up in connection with the Gardens, mostly in the last hundred years or so. However, I shall give a sketch of the early history of the gardens because of its general interest.

Kew, the more northern of the two estates, had a residence, "Kew House," as early as 1650, owned by Sir Henry Capel. He

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built the first gardens, and also two hothouses, an "orangery" for growing oranges, and a "myrtetum" for growing plants of the myrtle family (exactly why I am not sure, but perhaps for the spices allspice and cloves which are produced by members of this family, and very possibly the laurel family, which produces "bay leaves," cinnamon, camphor, benzoin, and other useful products, may have been included also, since families were not well defined in those early days). Kew was first acquired by the reigning royal family in 1730, when Frederick, Prince of Wales, son of George II, bought the property and resided there with his wife, Princess Augusta of Saxe-Gotha. This house was demolished in 1802. A house nearby, known first as the "Dutch House," had been built in 1631 by Samuel Fortrey. It had been occupied by the royal family since 1734 and was formally acquired by George III in 1781, since which time it has been known as "Kew Palace." It was shut up in 1818 and was not reopened until 1899.

Prince Frederick enlarged the gardens, but the credit for the establishment of a botanical garden with a scientific reputation is due to Princess Augusta. She was fortunate in choosing in 1759 as head-gardener a Scotsman, William Aiton, who had been employed by Philip Miller as a gardener in his "Physic Garden" in Chelsea. (Incidentally, Miller's Physic Garden is still very much in existence, although not always open to the general public; its pride is a giant specimen of a fern, *Todea barbara*, which was planted by Miller more than two hundred years ago.) A botanical garden for growing interesting exotics was formally started the same year on nine acres of ground surrounded by walls. The botanical garden included a "physic garden" for herbaceous plants, which were arranged by the Linnaean system (then only seven years old!), and an arboretum for trees and shrubs. The next year (1761), with the advice of Lord Bute, the prime minister under George III and a great plant-lover himself, Princess Augusta had the "Great Stove" built, which was the largest hothouse in England for over a century thereafter. It was demolished only in 1861. Princess Augusta also built the most conspicuous landmark of Kew Gardens even today, the Chinese Pagoda, constructed in 1761 and 1762 from a design by the eminent architect Sir William Chambers. It is a red structure, octagonal in shape, that rises 163 feet in height, high above even the tallest of the surrounding trees, and is thus easily visible for miles around. It is not now possible for visitors to ascend to the top as formerly, where a fine view of the surrounding country can undoubtedly be had, for the only nearby structure that is equally high is a rather unsightly gas tank on the northern bank of the Thames. The pagoda was built far outside the botanical garden in the area then known as the "Pleasure Grounds."

Richmond estate adjoined Kew on the south. Richmond Lodge (also known as Ormonde Lodge) was built about 1707 by the Duke of Ormonde. It later came into the hands of George II, who resided there much of the time because Queen Caroline favored the lodge. She was interested in plants also, and had a large formal garden. She was especially intrigued by summer houses and other architectural appurtenances. Some of these were fantastic even in an age given to the rococo, such as "Merlin's Cave," which contained a statue of Merlin surrounded by Queen Elizabeth and other royal personages, and "The Hermitage," which had busts of Newton, Locke, and other famous "natural philosophers." These buildings have long since disappeared completely, and even their location can only be conjectured now.

It is said that George II was on hostile terms with his son Frederick who lived in the adjoining Kew House estate. There were no joint gardens. The two estates were separated by a public road called rather inappropriately "Love Lane," which divided the present Kew Gardens into approximately equal parts. However, on the death of his grandfather George II and his father Prince Frederick, George III ascended the throne and inherited both properties. With him the hostility between the two estates came to an end and the two properties were united. He abolished "Love Lane" so thoroughly that its course is only approximately known today. As a substitute he built the present Kew Road which ran along beside both estates for use by the public, which was also permitted to walk along the river banks to Brentford.

The southern part of Richmond estate was a naturally wooded area known as the "Deer Park," which did contain deer, which were probably considered pets rather than animals for hunting, for the area is far too small for a fair "hunting ground." George III cut down the trees and transformed the Deer Park into a pasture, which it remains today essentially although still known as the "Deer Park."

After the death of Prince Frederick, Princess Augusta continued to live in Kew House until her death in 1772. Then George III immediately moved in. Although he was not personally much interested in gardening, he made one move that assured the continuing growth of Kew Gardens for almost the next fifty years—he selected Sir Joseph Banks, the famous botanist of Cook's first voyage, to be in charge of Kew. Banks never had the formal title of Director nor did he receive any compensation for his work, but nevertheless Kew's future success was largely due to him. Banks was evidently a man of enormous energy, with a hand in many ventures. He immediately decided to send out botanical collectors to get plants and seeds for Kew, probably at his own expense, since he was a wealthy man and George III was apparently not notably generous. The first one sent out was Francis Masson, who went to the Azores and South Africa. Among the other collectors were David Nelson, who had been an assistant botanist on Cook's third voyage (1776–1779) and later on that of Captain Bligh; Christopher Smith, who went on Bligh's second voyage (1791); and James Wiles, a Kew gardener who accompanied Smith as assistant botanist and who later settled in Jamaica. A little later Banks sent George Caley to Australia, Allan Cunningham to Australia and New Zealand (1814) and also to Brazil with another Kew gardener, James Bowie, who later went to South Africa to collect plants until 1823. William Ker, a young Scots gardener, was sent to China in 1803; he sent back seeds of a shrub that was named *Kerria* for him, now a beloved shrub of many gardens. During Bank's tenure as director, Kew did not have an herbarium. The specimens collected by the botantists mentioned above went into the personal herbarium of Banks, now in the British Museum.

The first botanical publication issued from Kew was the first "Hortus Kewensis" by Sir John Hill (1716–1775), who published this work containing descriptions of all the plants cultivated at Kew during those first few years prior to 1768. Hill was a rather eccentric but talented English gentlemen and botanist, who is best known for his lengthy "A Vegetable System" (1759-1775), a work much sought after today, the publication of which apparently was disastrous to him financially but which earned him a Swedish knighthood. A more important work issued from Kew in the early years was the three-volume "Hortus Kewensis" of William Aiton, published in 1789. Although this work is attributed on the title page to Aiton only, it is generally and doubtless correctly believed that it was not written by Aiton but in the beginning by Daniel Solander (1736–1782), botanist and librarian to Banks and completed by Jonas Dryander (1748–1810), also a botanist and librarian for Banks. An enlarged second edition was put out (1810–1813) in five volumes by the younger Aiton, but again the work (to about the middle of the third volume) was written by Dryander and completed by Robert Brown, although they are not given any credit. The new species published in these works must be attributed to the Aitons (except where otherwise indicated in the text), for theirs are the only names in the publication.

William Aiton (1731–1793) was not a trained botanist, but he was a competent supervisor for the gardens, which prospered under his leadership. The number of species introduced into cultivation during his tenure of 34 years was enormous. After his death in 1793, his son William Townsend Aiton (1766–1849) took over as head-gardener, a post that he retained for the next 52 years. I do not know much about the personality of the younger Aiton, but he was evidently not such a forceful personality as his father. However, Kew continued to prosper for many years, up until the death of Banks in 1820. After the death of Queen Charlotte in 1818, Kew was never again the residence of the reigning monarch.

Richmond Gardens were in the charge of a head gardener named John Haverfield for a great many years, actually until his death in 1784 at the age of 90. He was succeeded by his son, John Haverfield, Jr., who remained in charge until his retirement in 1795, at which time the administration of both Richmond and Kew was joined under the younger Aiton. Aiton was fortunate in picking in 1822 a young Scotsman, John Smith (1798–1888) to be in charge of propagating at Kew and later his chief assistant in 1826. He is an important man for fern students for his new system of classification of ferns published in 1841. His chief fern works were published more than 40 years after his appointment to Kew: the "Ferns: British and Foreign" in 1866 and the "Historia Filicum" in 1875.

W. T. Aiton was probably not a good administrator, and Kew's reputation began to decline after 1820. Things came to a climax after the death of William IV in 1837. Lord Surrey, the Lord Steward, decided in 1839 to convert the botanical gardens into economic gardens and the greenhouses into vineries, but protests from the public stopped him from carrying out these disastrous changes. (Incidentally, in just this spring of 1969, a similar rumor was published, that Kew was going to be turned into a place for research on economic plants for the benefit of undeveloped countries in Africa and elsewhere, which brought forth a flood of protests which are still continuing to be received even though Kew has stated repeatedly to the press that this rumor is completely false and it has been officially refuted in Parliament; it has even been printed here in the United States and elsewhere around the world, showing the general interest in the welfare of Kew.) A committee was appointed to look into the management of Kew Gardens, a committee that included Sir Joseph Paxton and, fortunately, the notable botanist John Lindley (1799–1865). The committee approached the Duke of Bedford, known as an enthusiastic gardener, and through his offices the administration of Kew was transferred from the Lord Steward to the Commissioners of Woods and Forests. Aiton resigned the directorship of the Botanic Gardens (1840) but remained in charge of the "Pleasure Gardens."

The Duke of Bedford was an acquaintance and admirer of Sir William Hooker (1785–1865), a professor of botany in the University of Glasgow, who had already acquired a great reputation by his "Flora Scotica" (1821), the "Icones Filicum" (1829–31), "The British Flora" (1830), the "Flora Boreali-Americana" (1833–40), and as an authority on bryophytes and ferns. In March, 1841, Hooker agreed to move from Scotland and accepted the offer of the Directorship of Kew (at a salary of £ 300 a year plus £ 200 for a residence!). The transferral of his extensive herbarium and library from Glasgow is said to have cost him his first year's salary.

William Jackson Hooker was already 55 years old when he became Director. He had been elected a Fellow of the Linnean Society when only 21 years of age. He went to Glasgow in 1820, after having spent five years in managing a brewery, a task apparently not to his liking. He was knighted by William IV in 1836.

On coming to Kew, Hooker confirmed the appointment of John Smith as curator. An immediate innovation was the admission of the public to Kew Gardens unrestrictedly. Previously it had been feared that the presence of the public unsupervised would be destructive, but it did not turn out so, except for one incident many years after Hooker's death. In February, 1913, a group of militant suffragette vandals descended on Kew Gardens for some unascertained reason, burned the tea pavilion, broke the windows in the orchid house, and destroyed many of the plants. Even two world wars saw less destruction.

Under Hooker's direction Kew began to expand again. A large new orchid house was erected (the tropical fern house of later years) and the present magnificant main gates were built in 1845. All of the "Pleasure Grounds" were added to the Botanic Gardens after the retirement of Aiton in 1845. They were to be used as an arboretum and were separated from the rest of the gardens by a fence until as late as 1895. In 1848 the largest hothouse was opened, the immense palm house. The former "Kitchen Garden" was given by Queen Victoria in 1849 to form the present herbaceous gardens. Altogether Hooker's charge grew from 15 acres when he came in 1841 to 650 acres by 1850, but the "Deer Park" was later removed from his direction.

Hooker continued the policy of sending out collectors, among them Purdie, who went to "New Granada" (Colombia) and Jamaica in 1843, and Burke, who was sent to northwestern North America in 1845. Purdie remained in the New World, being appointed supervisor of the Botanical Garden in Trinidad in 1845. Another man of this period and earlier who should be mentioned is Francis Bauer (born in Austria in 1758 and died at Kew in 1840), an exceedingly talented botanical artist, who lived on Kew Green and whose salary was paid by Banks, who left him a pension, so that he was able to continue drawing and painting for the next 20 years. His best known works are the paintings done for Hooker and Bauer's "Genera Filicum" (1842), which have rarely been equalled for artistic beauty as well as botanical accuracy.

After coming to Kew, Hooker continued to be productive botanically. He contributed descriptions to the "Botanical Magazine," to his "Icones Plantarum," edited various journals of botany, and expecially worked on ferns. His major work on ferns, the five-volume "Species Filicum" (1844–1864), is unique in the history of pteridology. In it he not only described technically all the ferns of the world but also commented on them and on other fern students so much that the work is almost readable in parts. I recall my former colleague Dr. Maxon saying to me that Hooker "bared his soul" in a way that no other fern student ever did. Hooker kept to an extremely conservative view regarding fern genera (and species too), developing an artificial system based almost solely on soriation, and disregarding the numerous and often well-founded genera proposed by Presl, John Smith, Fée, and others. Following the publication of this detailed work, Hooker started on a one-volume reduction of it to be called "Synopsis Filicum," which would have abbreviated descriptions, comments, synonymy, and citation of specimens. Unfortunately, Hooker died suddenly in 1865 at the age of 80 before finishing this "Synopsis," the completion of which was entrusted by Hooker's son to J. G. Baker, who brought it out between 1865 and 1868. However, Hooker did write the preface, dated April, 1865, not long before his death, in which he gives some of his philosophy regarding the recognition of genera and species. In this he stated that he "feels satisfied that the doubtful and imperfectly described species form the greatest obstacle to any satisfactory advance in descriptive Pteridology." (And all such species unknown to him from specimens were omitted in the "Synopsis.") Hooker's statement reflects a rather general disinclination in the nineteenth century to borrowing material for study, in part possibly attributable to the uncertainties of the postal service in those days and partly to the lack of our present type concept. Instead of examining types, authors tried to identify species from the original descriptions only, as Hooker did with most of the species described by Kunze, Mettenius, Presl, and Fée. I believe that there is no evidence that Hooker ever borrowed any specimens for study from these or other authors. In fact, he sometimes guessed regarding the identity of species described by John Smith, even though Smith's personal herbarium was available for consultation right there at Kew. Another drawback to Hooker's work is his lack of appreciation of natural geographic ranges. Despite its usefulness, even today, the "Synopsis Filicum" had a deleterious effect on pteridology, for botanists tended to think it the last word, and that there was nothing further to be learned about ferns.

Hooker's son, Sir Joseph Dalton Hooker was born in Suffolk in 1817. He became an outstanding systematist. At the age of 22 he went on the "Erebus" to Antarctica, and the results were published over a period of 16 years in his "Flora Antarctica," "Flora Novae Zelandiae," and "Flora Tasmaniae." In 1847 he went to India and collected, partly with Dr. Thomas Thomson, for more than three years. His travels are interestingly described in his "Himalayan Journals." He was instrumental in introducing into cultivation many of the beautiful rhododendrons that are now so popular with gardeners. After his return to England he was appointed Assistant Director at Kew in 1855, and after his father's death he became Director until his voluntary retirement in 1885 at the age of 68, in the belief, supported by his doctor, that he had arteriosclerosis and would not live more than two years. Medical science not being infallible, Hooker lived for another 26 years and was still at work on a monograph of the difficult genus *Impatiens* four days before his death in 1911 at the age of 94. Hooker became famous for his masterpiece, the "Genera Plantarum," published in collaboration with Bentham between 1862 and 1883, still a fundamental reference work for its exact descriptions of the genera of angiosperms, and for his "Flora of British India," the last volume of which was completed only in 1899.

Both the Hookers were voluminous correspondents; the letters of Sir William Hooker occupy 76 bound volumes at Kew, and a large lot of additional correspondence has just recently been acquired. A most interesting biography has recently been published—"The Hookers of Kew," by Mea Allen.[1]

The most prominent botanist associated with Kew during the Hookers' tenure was George Bentham. He was born September 22, 1800, in Plymouth. As early as 1823 he visited Glasgow to consult the elder Hooker, and the association with the Hookers continued throughout his life. His early work was mostly monographic studies on Labiatae, Scrophulariaceae, and Leguminosae, partly for the De Candolle "Prodromus" and partly for Martius' "Flora Brasiliensis." In 1854 he gave his herbarium to Kew and settled at Kew for the rest of his life, which was spent in writing the seven volume "Flora Australiensis," still the only complete flora of Australia, and especially the "Genera Plantarum" mentioned above, which contains more than 3,500 pages of concentrated descriptive matter in Latin and which took a quarter of a century to write. Bentham died shortly after the completion of this work at the age of 83. He left his wealth to Kew, and the Bentham fund (now administered by the Bentham-Moxon Trust, of which the Director of Kew is Chairman) is still available to be drawn on. Bentham, despite his closeness to Hooker never had a formal connection with Kew as a staff member although he spent much

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[1] Published by Michael Joseph Ltd. 22 Bloomsbury St., London, W.C.1, England. 50 shillings.

of his life there. He kept a daily diary, now in the Kew library, for over 70 years, a feat not often equalled.

Following Hooker's retirement, his son-in-law William Turner Thiselton-Dyer (1843–1928), who had been Assistant Director since 1875, was appointed Director. In his tenure of 20 years an alpine house and a house for filmy ferns were constructed. He started the "Kew Bulletin of Miscellaneous Information" (now merely the "Kew Bulletin") in 1887 and published the "Index Kewensis" in 1895 with funds supplied by the estate of Charles Darwin. This fundamental reference work was compiled by Dr. B. Dayton Jackson (also well known for his useful "A Glossary of Botanic Terms"); it lists all the described living genera and species of phanerogams published between 1753 and 1885, and included about 380,000 names. Kew has published many supplements, at present every five years. Special staff members are hired to scrutinize the new literature to keep the supplements up to date. There is a rumor going around that Kew is considering the use of a computer for the publication of future Supplements. Time will tell if this is correct. Thiselton-Dyer was considered something of a martinet by his staff and contemporaries and apparently was not well liked. He resigned voluntarily in 1905.

The Director between 1905 and 1922 was Sir David Prain, a taxonomic botanist with extensive experience in the tropics. He had been curator and later superintendent of the Royal Botanic Garden, Calcutta, for nearly 20 years. His major floristic work was "Bengal Plants (A Flora of Bengal)" published in 1903. Later he did monographic work with Burkill on *Dioscorea*. He rejuvenated the "Kew Bulletin," which had for some years been reduced mostly to appendices, and as James Britten remarked "was dying of appendicitis." Sir Arthur William Hill (1875–1941) was Assistant Director from 1907 and Director from 1922 to 1941, when he was accidentally killed when thrown from a horse. He was succeeded by Sir Edward Salisbury who was Director until his retirement in 1956. During the last war there was only minor damage to Kew, but members of the herbarium staff were on firefighting duty every night from September, 1939, to March,

1945. About one-third of the herbarium and many of the books were removed to Oxford in 1940, and another third moved to Gloucestershire in 1941. The Wallich Herbarium was stored in the Tring Museum. The present Director, Sir George Taylor, an authority on *Meconopsis* and *Potomogeton*, was appointed to the post in 1956, having previously been Keeper of Botany in the British Museum (Natural History).

THE HERBARIUM

When Hooker arrived at Kew in 1841 there was no organized herbarium, although a few specimins were stored in a garden shed. The Aitons did not make many herbarium specimens and those that were made were mostly preserved in the British Museum or in the private herbarium of Sir James Edward Smith, now in the Linnean Society. Hooker brought along with him the large private herbarium that he had built up while in Glasgow, but this remained private, although botanists were permitted to consult it freely The official herbarium dates only from 1852, when the personal herbarium of Dr. W. Arnold Bromfield was presented by his heirs. The next year George Bentham presented his extensive herbarium to Kew, and after the death of the elder Hooker in 1865, the Government in 1867 purchased his herbarium. Hunter House, on the north side of Kew Green, had been Government property since 1823 and had been lent to Hooker for storing his herbarium in 1852. After 1866 it was the official Kew Herbarium. Since that time it has been extensively enlarged, a wing (now called "C") having been added as early as 1877, Wing B in 1903, and Wing A in 1932. Just this year, in May, 1969, a fourth wing was opened by Queen Elizabeth II. This newest wing is a great improvement in its air-conditioning and appointments, especially in the magnificent new library which occupies a whole floor. For the first time the books are arranged so that a visitor can find them easilywithout assistance, and the working space by the windows is ideal. One of the features of the new library is a special room of "Kewensia," which has all the books and records in the library on the history of

Kew. Among the many interesting items is a manuscript diary of John Smith.

Kew has a large staff and many non-staff members work there who have been seconded from abroad. There are specialists on grasses, orchids, ferns, fungi, and cultivated plants, but most of the phanerogamic botanists are assigned a geographic area (although this system is in the process of being reorganized along systematic lines, with staff members being responsible for various groups of families; both systems have their advantages, both for the staff members and the institution). The general herbarium is arranged mostly by published floras and monographs. The species are sorted into 18 major geographic divisions, some of which (like "Tropical Africa") are generally subdivided further.

The Kew Herbarium has a good representation of plants from all over the world, although rather on the meager side in the plants of China, Japan, the United States, Canada, and Alaska. The regions best represented are naturally those that are or were parts of the British Empire, especially tropical and South Africa, Australia, New Zealand, Malaya, and India. The number of type specimens is enormous, estimated at 200,000, and I would put the figure well above that, if one considers isotypes and isosyntypes also.

A special treasure of Kew is the herbarium of the East India Company, assembled by Nathaniel Wallich in the early years of the nineteenth century. It contains the voucher specimens for Wallich's "A Numerical List of the Dried Specimens of Plants in the East India Company's Museum" (1828). Although this is as specified a list with only numbers, localities, and names, but without descriptions, the new species were accepted as validly published by Hooker and some other early botanists on the basis that the species concerned could be identified by the numbered specimens in the herbarium and distributed rather widely by Wallich. Unfortunately, sometimes these *nomina nuda* are listed in Christensen's "Index Filicum" also as though they were validly published. Many of them *were* validly published by later authors, but these later references are often not given by Christensen. The East India Company Herbarium is maintained at Kew in separate cabinets, and the specimens are arranged mostly as in the published "List." However, there are some unexplained gaps with many missing numbers that were presumably once there. This herbarium is important especially for localizing the specimens. Although Wallich often cited as many as seven or eight different collections under a number, the specimens distributed often bear only the List number and lack the locality data. Since Wallich often confused two or more species, often rather unrelated, under a single number, the locality data for a soecimen can be obtained only by matching up with the specimens in the Wallich Herbarium. Most of the specimens in this Herbarium are not types but isotypes, since the validly published species were described from duplicates that were distributed to Kew and elsewhere. Because of these frequent mixtures, specimens of Wallich numbers in different herbaria need to be scrutinized carefully; they can not be assumed automatically to be isotypes. It would be worthwhile to have the whole East India Company Herbarium photographed and microfiches made available for sale. As it is, many students come to Kew and are never even aware of the existence of the herbarium.

The Keepers of the Herbarium at Kew since its organization are: Daniel Oliver (1863–1890), John Gilbert Baker (1890–1899), William Botting Hemsley (1899–1908), Otto Stapf (1908–1922), Arthur D. Cotton (1922–1946), William B. Turrill (1946–1957), Charles E. Hubbard (1957–1965), J. P. M. Brenan (1965–present). The number of well-known staff members is far too great to list all of them; the deceased include N. E. Brown, C. H. Wright, R. A. Rolfe, J. F. Duthie, F. A. Sprague, and N. Y. Sandwith(dearly remembered by many visitors); others, mostly retired, are John Hutchinson (since 1904 and still actively working every day!), M. L. Green, J. S. L. Gilmour, V. S. Summerhayes (since 1924), H. K. Airy-Shaw (since 1925), F. Ballard (since 1929), A. A. Bullock (since 1929), J. R. Sealy (recently retired), and E. W. B. H. Milne-Redhead (since 1929 and now Deputy Keeper).

Hooker's "Icones Plantarum" was first begun in 1836 and is still being published by Kew through funds from the Bentham-Moxon Fund. It is intended for the illustration of plants represented at Kew by herbarium specimens rather than living material (as in the case of the "Botanical Magazine"). It appears at irregular intervals and is in black and white only. The "Icones" contain many plates drawn by the elder Hooker himself and over 1,600 by the talented artist Walter Fitch, who was trained by Hooker.

At present the staff at Kew is primarily working on the "Flora of East Tropical Africa," the "Flora of West Tropical Africa," the "Flora Zambesiaca," the "Flora of Cyprus," and the "Flora of Iraq." The "Kew Bulletin" contained originally mostly papers on economic botany, but now consists of technical papers, mostly by staff members. It has been published continuously since 1887 except for a break during World War II.

The "Botanical Magazine," the earliest botanical periodical still being published, was begun in February, 1787, by William Curtis (1746–1799). It consists of colored plates, with descriptive text, of plants cultivated in the British Isles. After Curtis' death, the magazine was edited by John Sims until 1826, then by Samuel Curtis, the nephew of William Curtis. William Hooker took over the editorship in 1845, and since that time a member of the Kew staff has always been the editor, although the magazine is not published by Kew. For 77 years the magazine was edited by the two Hookers, who also wrote most of the text. Up until 1947 the plates were all hand-colored.

FERNS AT KEW

Ferns have seemed to be a specialty at Kew from almost the beginning. John Smith, the first curator, was a fern man primarily. When he first cane to Kew in 1822, there were only about 75 species cultivated. Smith increased this to 850 in 1868, and others after him to 1116 in 1895. These ferns were listed at this time by J. G. Baker in a publication from Kew entitled "Hand-list of Ferns and Fern Allies Cultivated in the Royal Botanic Gardens" (London, 1895). Baker's name does not appear as the author, but there is internal evidence that he prepared the text. This list is of importance in that it not only indicates the species in cultivation at the time but also because there are a great many new varietal combinations published in it, none of which have ever been indexed or quoted in revisions. The work itself is quite rare or at least hard to locate because of its anonymity. I do not know the number cultivated at present, but it must be well over a thousand species. They include now many species collected rather recently in Ceylon, New Guinea, Jamaica, and Trinidad that have never been in cultivation before.

John Smith's own personal fern herbarium went to the British Museum, but duplicates of most of his species are at Kew. The Hooker Herbarium, indicated by a special stamp, contains far too many important collections for me to list them. The chief ones that were used in writing the "Species Filicum" were listed by Hooker in the preface to the first edition of the "Synopsis Filicum." The younger Hooker was not much interested in ferns, although he did publish a few new species from his own collections in New Zealand and from Darwin's Galápagos material. After the death of the elder Hooker, Kew had another fern specialist, J. G. Baker, who completed the "Synopsis Filicum" and continued with fern work for another 50 years or more, since he lived to be 86. He was an interesting character and deserves a fuller account than I can give here. More recently the ferns were in the competent charge of Mr. Francis Ballard, now retired but who still often comes in to work. At present they are in the charge of Dr. Frances Jarrett, who is currently working on monographic studies on the genus *Nephrolepis* and on an account of the ferns for the "Flora of East Tropical Africa."

The result of having had curators interested in ferns is that the collections are more reliably named than in most herbaria, with the exception of Berlin. Dr. Jarrett has undertaken the much-needed work of separating the collections geographically. This rearrangement is an enormous task that will take years to complete. I have found in working at Kew in 1967 and again in 1969 that the rearranged genera were far easier to consult. One rather unfortunate thing at Kew is that Hooker often mounted several different collections on the same sheet without carefully indicating which label goes with which specimen. The matter is of importance since sometimes these collections represent different species even though Hooker thought them the same. There are no figures available as to the size of the fern herbarium, but I judge that it probably ranks third, behind Paris and Berlin and just ahead of the U. S. National Herbarium.

The most valuable types at Kew are those of Hooker, although from another point of view this is not necessarily so. All types, of species at least, are of about equal value, and those of Hooker might be thought of less value ultimately, since his species were well described and often illustrated also, and so are generally correctly understood, whereas the species of some other botanists, like those of Roxburgh, were so poorly described as to essential characters that even their genus is uncertain. The types of the latter species are especially important, since the species can not be identified at all in their absence.

Among the most important collections at Kew is the herbarium of Thomas Moore. The exotic plants of Moore's herbarium, including his types, are distributed in the general herbarium, but his British plants, including the original collections of the numerous "monstrosities" that were found and named in the middle of the nineteenth century, are kept in a separate herbarium, fortunately. The British plants are gradually being incorporated, but not the monstrosities. Thet are probably not much used at the present time, but they do have potential value.

Another special collection of great value is that received from Col. Beddome, which formed the basis of his "Ferns of British India" and "Ferns of Southern India." Beddome has carefully indicated those sheets that are the originals of his plates, and which are thus the types of his new species. Hooker did the same thing very often, and often affixed copies of the original drawings to the sheets from which they were made. There are also numerous Beddome specimens in the British Museum, which need to be compared carefully with the Kew specimens in order to decide on lectotypes.

Kew also has a fine collection of published and unpublished drawings and paintings of ferns.

The ferns were until recently quite crowded, but they have now been moved to the spacious top floor of the new wing. The working tables here have a delightful view of the River Thames, with its busy river traffic and numerous wild birds. The ferns are stored in built-in cabinets, which unfortunately do go up to the ceiling as in the old wings and thus necessitate the use of ladders. However, at the present time the upper pigeonholes are empty and reserved for future expansion.

I have always been very cordially received at Kew by the Keepers and the scientific staff and it has been a pleasure to work there. I am particularly grateful to Dr. Jarrett and Mr. Ballard for many courtesies. Over the years I have taken about 4,500 photographs of ferns at Kew, mostly of types and isotypes, but also of a number of interesting specimens from Fiji which I propose to use in a projected fern flora of Fiji on which I have been working for many years. Kew, with its early collections from Fiji of Horne, Harvey, Milne, MacGillivray, Seemann, Macleay, and others, is the richest herbarium in the world for the study of Fiji ferns, although American herbaria, particularly the Gray Herbarium, the Bishop Museum, and the National, Herbarium have the best recent material.

The above account of the herbarium has been drawn largely from personal observation, but the historical facts are taken chiefly from two books: W. J. Bean's "The Royal Botanic Gardens, Kew: Historical and Descriptive" (Cassell & Co., Ltd., London, 1908), and "The Royal Botanic Gardens Kew, Past and Present," by W. B. Turrill, 1959.

(*To be continued*)

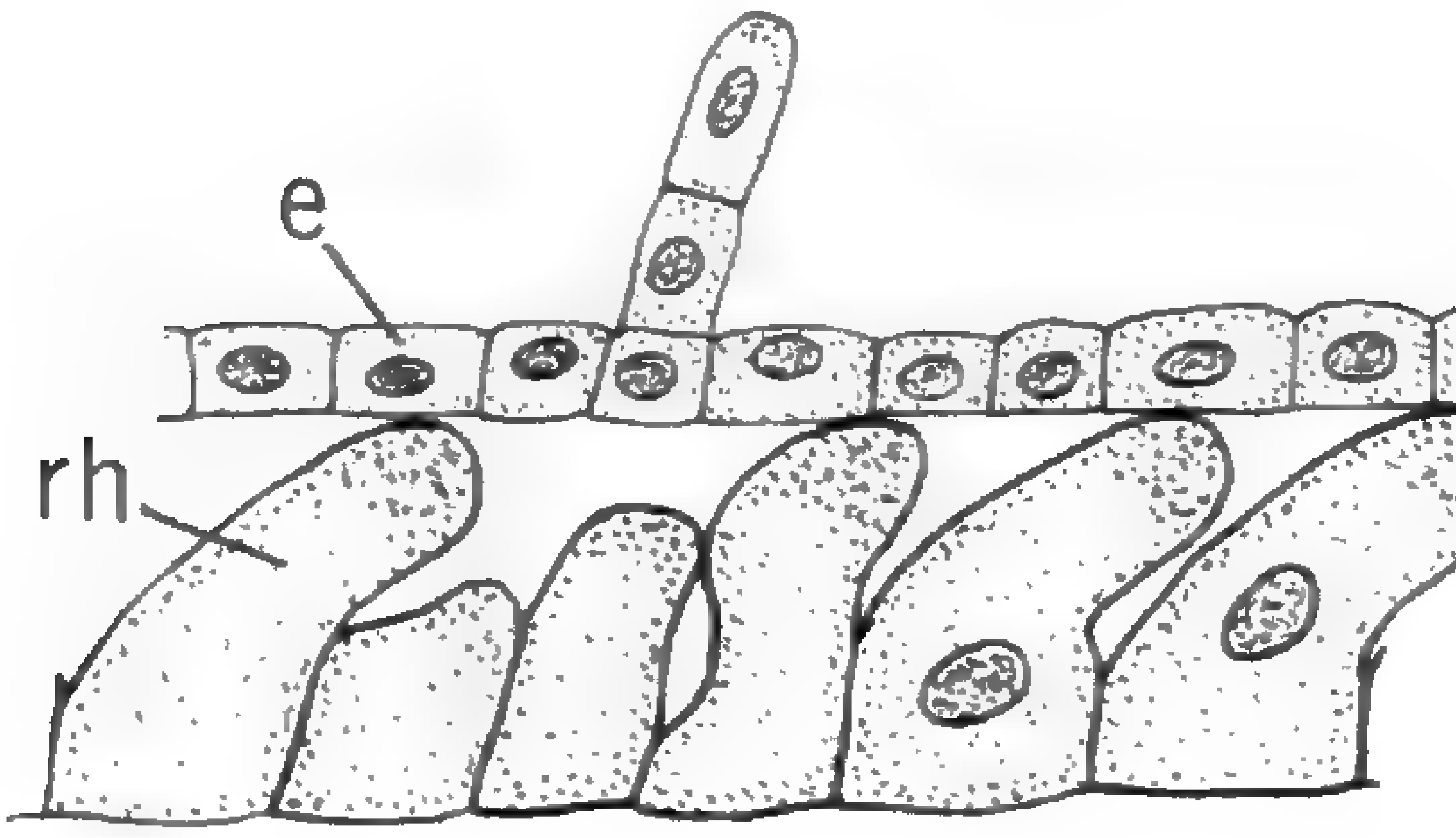
Rhizoids and Root Hairs of Ferns

HELEN M. PEARSON

Probably a first adaptation of green plants to terrestrial life was the development of absorptive trichomes or rhizoids. The axis bearing these rhizoids incorporated geotropic mechanisms and evolved a self-protecting pattern of mitosis at its apex, becoming a "root." The recent work of Bierhorst (1968) and Roth (1963) in showing some relationships of *Psilotum* and *Tmesipteris* to the Filicales suggests the probability that all living vascular plants have descended from a single ancestor with roots, and that rootlessness in vascular plants is derived.

Fern roots are usually very distinctive. The stele itself is nearly always colorless, but it is surrounded by one to several layers of heavy, brown, sclerified cortex. In many ferns the old cortex becomes a dense, almost black mass. In small roots there are usually only one or two sclerified cortical layers of cells surrounded by a layer of larger cells and usually a subepidermal layer with a more or less sclerified outer wall. In larger roots there are more cortical layers. The inner surface of the outermost cortical walls is likely to be studded with brown (phlobaphene?) tubercles; in extreme cases cortex, epidermis, and root hairs are full of such tubercles. Usually the impregnating material in the cortex is deposited in easily visible spirals with conspicuous pits between the gyres.

In modern usage the term "root-hairs" usually refers to trichomes borne on roots, and "rhizoids" to absorptive trichomes borne on gametophytes or sometimes on sporophytic tissues. Both are believed to have the functions of absorption and anchorage. Traditionally, rhizoids have been defined as trichomes borne on gametophytes and root hairs as trichomes borne on sporophytic roots or rhizomes (Haberlandt, 1909). However, Haberlandt did not know about the confusing similarities between the gametophytes and the subterranean axes of the sporophytes in the Psilotaceae, and in those days exaggerated importance was



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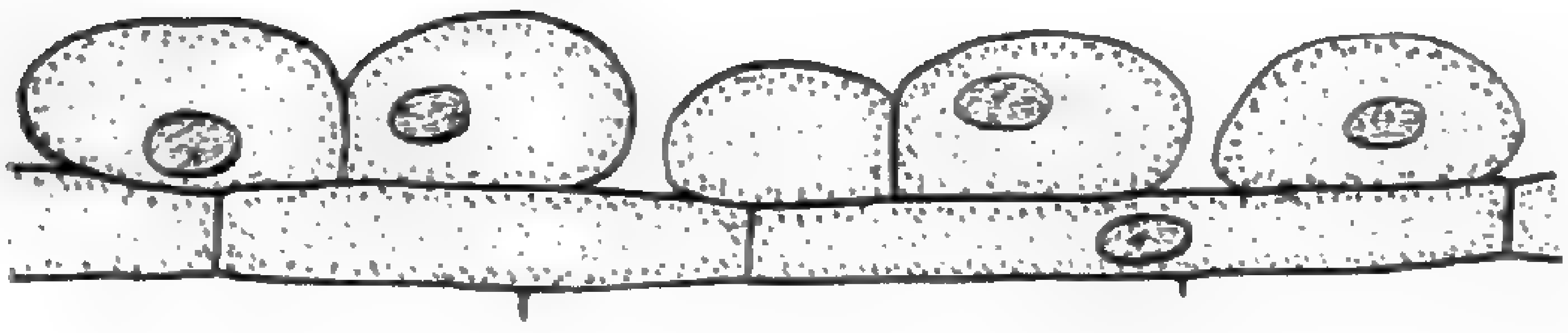

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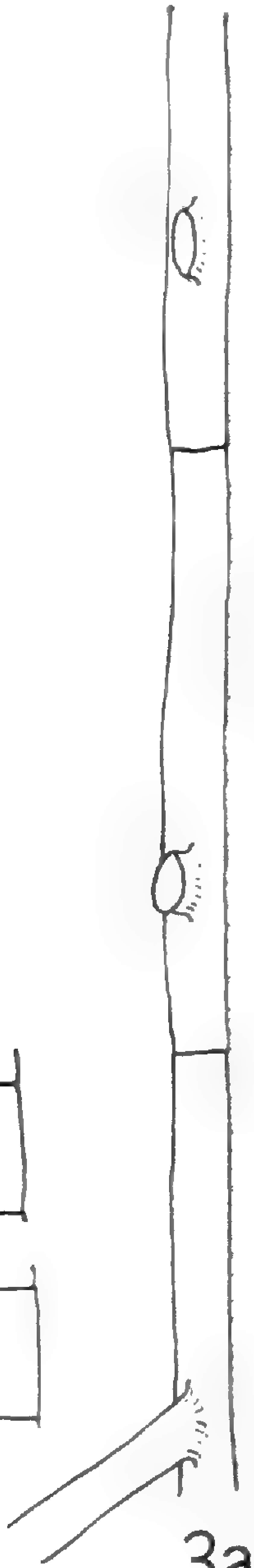

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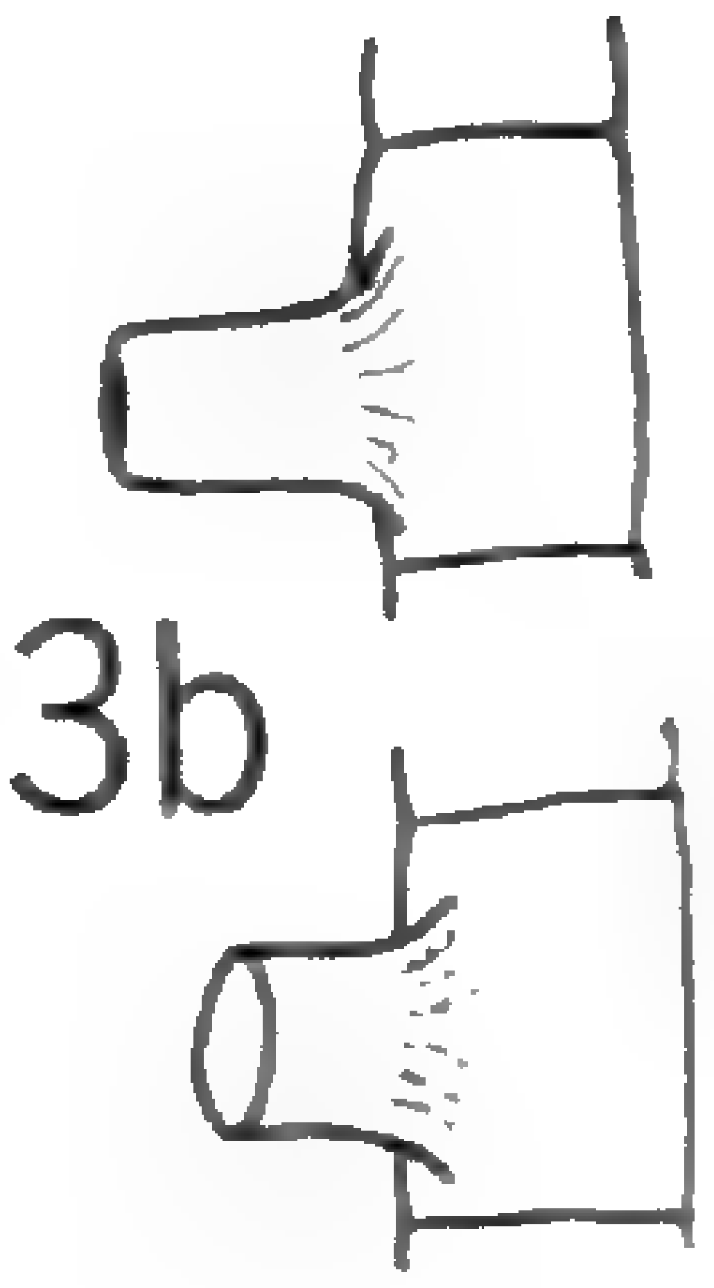

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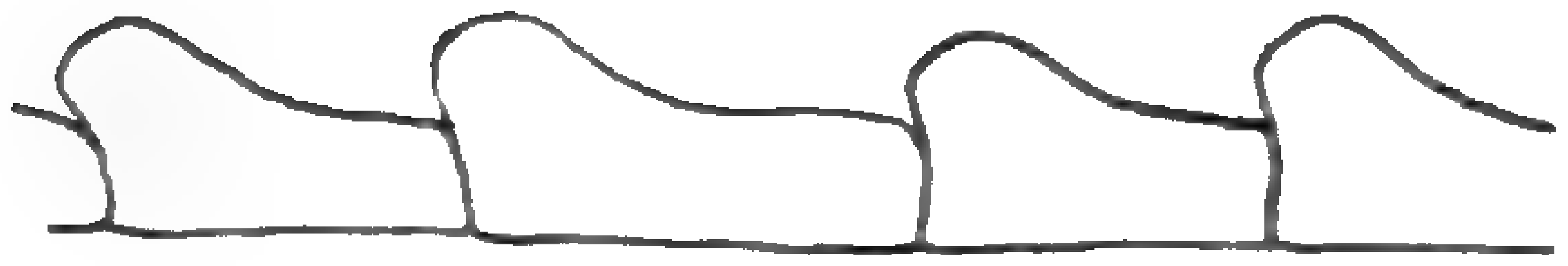

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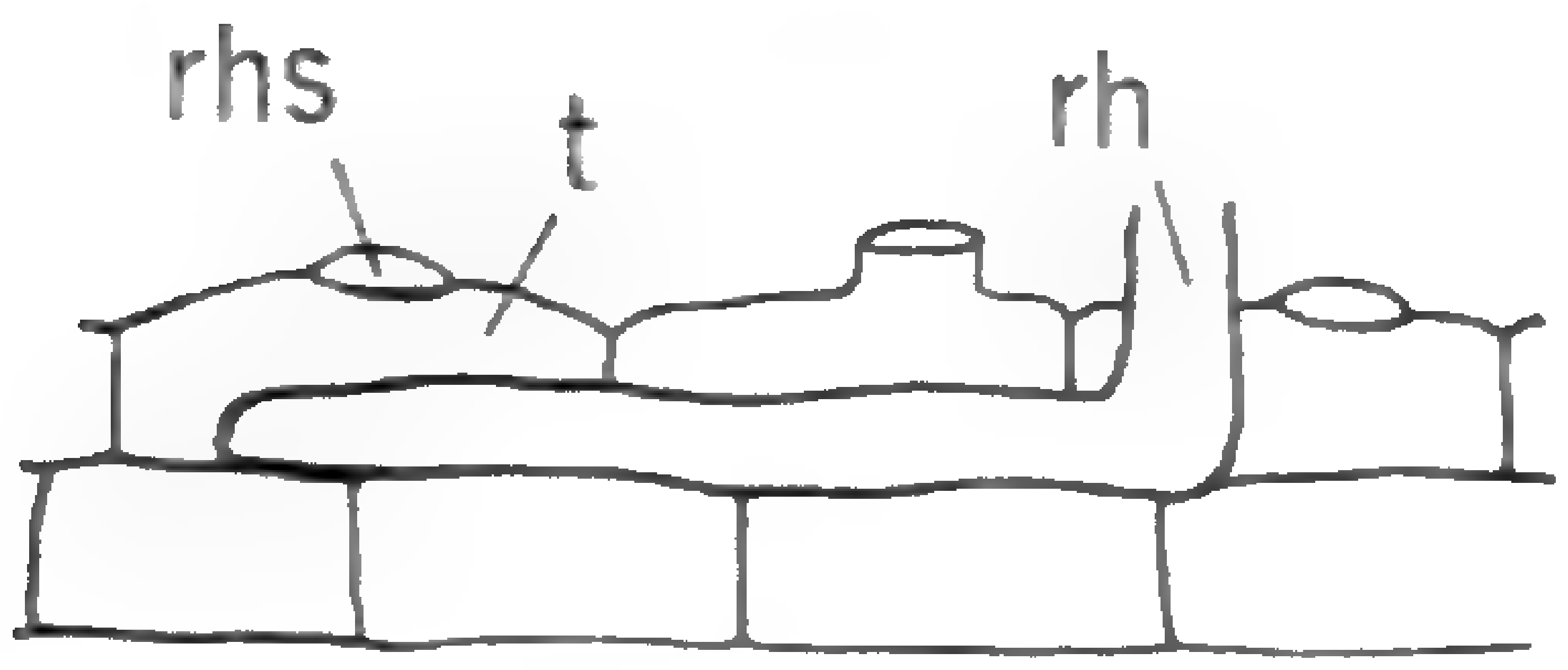

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FIG. 1. DESCENDING AXIS OF OLEANDRA COSTARICENSIS NEAR TIP. FIG. 2. YOUNG ROOT EPIDERMIS OF POLYPODIUM VULGARE. FIG. 3a. LONG, HEALTHY EPIDERMAL CELLS OF CAMPTOSORUS RHIZOPHYLLUS ROOT. FIG. 3b. SHORT EPIDERMAL CELLS OF C. RHIZOPHYLLUS ROOT WITH SICKLY APEX. FIG. 4. TYPICAL ROOT EPIDERMIS OF POLYPODIUM PILOSELLOIDES. FIG. 5. ADHESIVE ROOT HAIR OF PLATYCERIUM BIFURCATUM. The abbreviations are: E = STEM-TYPE EPIDERMIS, RH = ROOT HAIR, RHS = ROOT HAIR SCAR, T = TRICHOBLAST.

attributed to the distinction between haploidy and diploidy, since nothing was known of the processes by which biosynthesis is controlled. It might be better if root hairs were defined as merely "rhizoids on roots," which would avoid an artificial distinction as well as the inconsistency of ascribing "root" hairs to the rhizomes of Psilotaceae, to certain Hymenophyllaceae, and to root-hair-like trichomes induced in various other locations on other plants (La Rue, 1946). Cormack (1962) postulated that "a root hair is simply an elongating epidermal cell that has changed its direction of growth." However, root hairs do not grow in a pure culture of identical cells, and one must observe adjacent tissues and the plant as a whole to search for the factors related to trichome development.

The root epidermis generally bears a particular kind of hair that is different from the trichomes of the shoot epidermis of the same species. This difference is shown particularly clearly in the root epidermis and the adjacent epidermis of the anomalous masses of tissue that appear on the bases of roots of the dissected-leaved cultivars of the Boston fern, *Nephrolepis exaltata* var. *bostoniensis*. There is an abrupt transition from the typical files of elongated epidermal cells of the root to irregular swirls of anomalous epidermal cells, and accompanying this there is a change from a typical root hair to a very short, uniform, septate, stem hair. This is an especially conspicuous case of a correlation between the transition from a root to a shoot epidermis and from a root to a shoot hair.

Another interesting case occurs in *Oleandra costaricensis*, which has positively geotropic naked axes descending from the nodes. These have exposed apical cells and are sparsely beset with septate hairs. On approaching (or actual?) contact with the soil, the apical cells begin to cut off rootcap cells periclinally. This results in a transition zone in which a typical stem epidermis with short, septate hairs and also one or two subepidermal layers are pushed off by root hairs developing on cortical cells (*Fig. 1*). These cortical cells have thus been transformed into root epidermis. At this stage the root epidermal layer has already developed its distinctive color. This process in *Oleandra* is different from the development of roots from rhizophores in *Selaginella*, although outwardly it appears similar (Webster and Steeves, 1964).

The observations reported here were made in connection with a survey (conducted for Dr. David Bierhorst at Cornell University) of the patterns of trichoblasts (hair-bearing cells) and hairless cells in the epidermises of fern roots. A few of the 105 ferns studied were collected from nature or gardens, but most were potted single plants or clones. I want especially to thank Dr. Helen Mar Beard of the Botanical Garden of the University of California at Berkeley for the many ferns made available to me there.

CELL WALL STRUCTURE IN ROOT EPIDERMIS

In all the ferns I have studied, with the exception of *Helminthostachys* of the Ophioglossales which has no root hairs, the epidermis is stained distinctively and must possess certain distinctive chemicals. In some cases there appears to be an internal gray sheet and an outer brown one in the walls of the trichoblast and its hair. The gray sheet seems especially prominent in the walls of the root epidermal cells, and not in the hairs. Its color blends with the deep brown of many fern roots to give a typically purplish or chocolate coloration. In those ferns with a strong pattern of trichoblastic and hairless cells, there is an extreme difference in wall appearance between the two types.

The epidermal cells contrast with the hypodermal layer not only in color but also in wall structure. The heaviest cortical wall, outside the stelar sheath if there is one, is usually adjacent to the epidermis. Spiral reinforcements are common in cortical cells, but in only a few cases could any indication of spiral structure be detected in the brown deposits of the epidermal cell walls, and then only in wide, irregular patches. Diffuse, more or less spiral epidermal bands occur in *Trichomanes dentatum*, *Vittaria elongata*, *Hymenophyllum laciniosum*, and on the hairless epidermal cells of a species of *Lindsaea*. Fern root epidermis, like that of angiosperms, has distinctive cementing properties, for rootcap cells do not stick to it. In many cases epidermal cells do not adhere to each other very well (*Fig. 2*).

DEVELOPMENT OF EPIDERMAL ROOT HAIRS

In some species of Polypodiaceae the trichoblasts become rounded and tend to be pulled apart by the elongation of the cortical cells beneath (*Fig. 2*). Later, they swell and become crowded. The hairs, when and if they are formed,[1] tend to taper gradually from a broad base. At the other extreme, and more commonly in most ferns, the trichoblasts keep pace with the elongating outer cortical cells beneath. The outer epidermal walls may bulge little and the hairs emerge abruptly with a uniform diameter for at least some distance (*cf. Figs. 3a* and *8a*). The hair may emerge anywhere from the middle of the trichoblast to the end nearest the root tip. Typically, the cell begins to bulge at about the middle when it is short, and the final position of the hair apparently depends on the relative elongation of the two ends of the trichoblast. This is determined in part by genetic factors, according to Row and Reeder (1957). Although hairs typically are borne in acropetal succession, there appears to be a considerable range of time over which a cell is capable of putting forth a hair (Rosene, 1954). Short hairs can frequently be found among long ones, but the short hairs are possibly due to arrested development. Cormack (1949, 1962) and others (e.g. Farr, 1928) have described the physiological factors involved in root hair production and elongation. Even in species with very long epidermal cells, fungal infection can reduce epidermal cell size to the range of species with the shortest cells (*Fig. 3*), for trichoblasts and their hairs are very sensitive to the environment.

Sometimes every cell will bulge, whether or not a hair is produced. Thus, the epidermis of *Polypodium piloselloides* has a knobby appearance even in areas where there are no hairs (*Fig. 4*). Many ferns do not produce any hairs at all on most cells of the root epidermis. On the other hand, some roots (as in *Osmunda*

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[1] Hairs are usually copious in the Polypodiaceae, *s. str.*, I have observed. The short trichoblasts and the wide bases of the trichomes make it appear that there is an unusually strong growth component perpendicular to the root surface in this family.

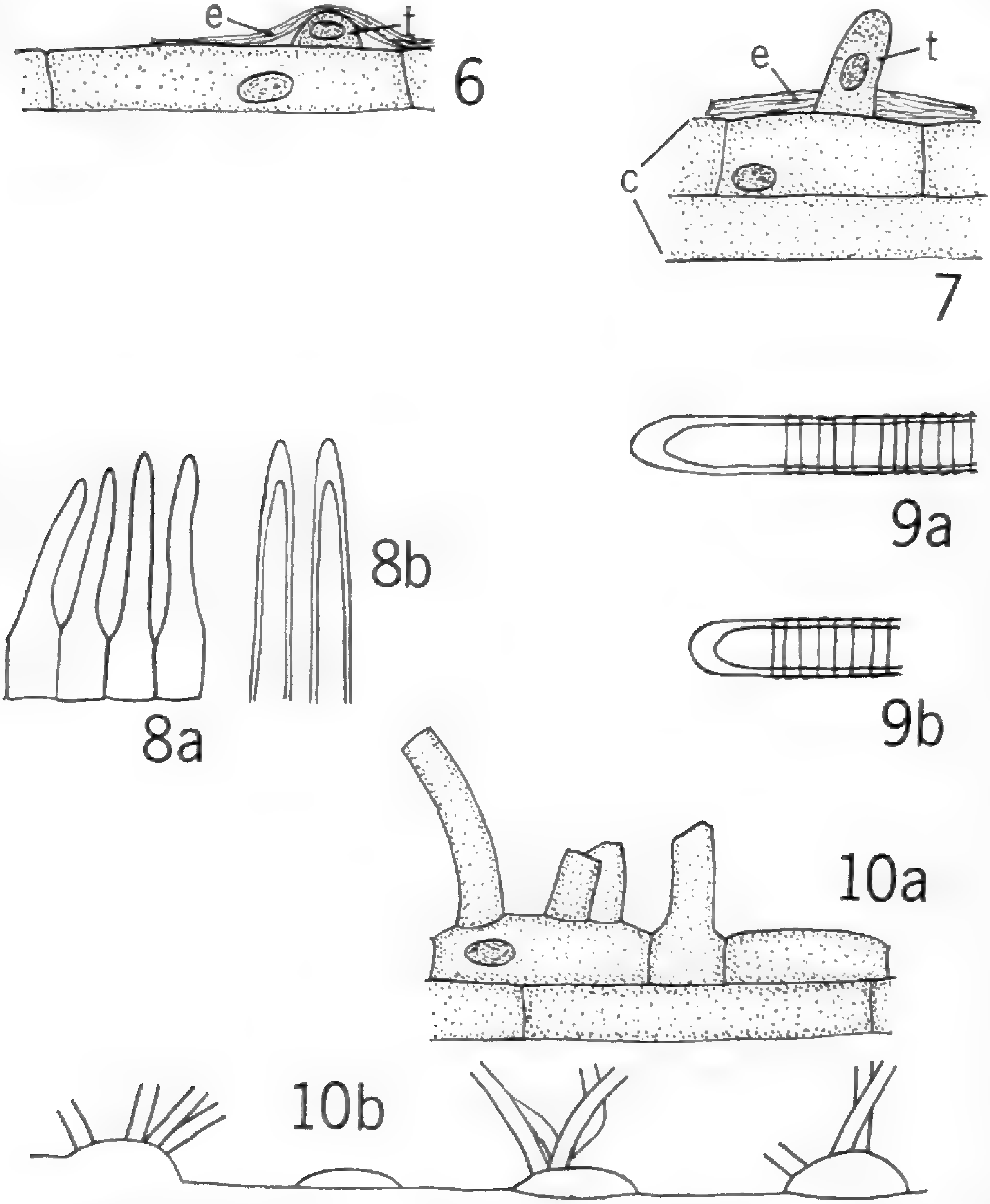


FIG. 6. ROOT HYPODERMAL CELL OF HECISTOPTERIS PUMILA. FIG. 7. SAME, OF VITTARIA ELONGATA. FIG. 8a. TRICHOBLASTS WITH ROOT HAIRS OF PYRROSIA. FIG. 8b. THICKENED ROOT HAIR TIPS OF PYRROSIA. FIG. 9a. BANDING ON ROOT HAIR OF HYMENOPHYLLUM LACINIOSUM. FIG. 9b. BANDING ON HAIR OF TRICHOMANES MEMBRANACEUM RHIZOME. FIG. 10a. TRICHOBLASTS WITH MULTIPLE HAIRS IN HECISTOPTERIS PUMILA. FIG. 10b. SAME, WHOLE MOUNT; CELLS LACKING TRICHOMES ARE COLLAPSED. The abbreviations are: C = CORTEX, E = COLLAPSED EPIDERMAL CELLS, T = TRICHOME.

cinnamomea) are characteristically very woolly from prolific hair growth without much cementing material. Others with much mucilage are so covered with particles of soil that one can only guess that there are root hairs underneath. The root hairs of *Platycerium* and many other ferns flatten themselves against surfaces, lobing and branching and cementing themselves to make a more or less solid tissue, a pseudoparenchyma. The roots of both species of *Davallia* studied were encrusted with *Sphagnum* because all of the root hairs had invaded the *Sphagnum* water storage cells. Root hairs sometimes cement themselves like stalks into old sporangia, or along the contours of the epidermis of their own or another root (*Fig. 5*).

CORTICAL ROOT HAIRS

Root hair production is not limited to the epidermal cells. Leavitt (1904) in an extensive survey showed that vascular plant root epidermis is of two types—undifferentiated and differentiated into various patterns of trichoblastic and hairless cells, and that the underlying hypodermal layer of cells is also sometimes differentiated. In this layer he found elongated cutinized cells alternating with short, uncutinized "transfusion" cells. The latter were also called "passage" cells by Haberlandt (1909) and others before him. Pinkerton (1936) investigated a number of species of Commelinaceae and a species of *Philodendron* (Araceae) and found a persistent hirsuteness of cortical origin. She also reported indications that cortical hairs occur in some other monocotyledons as well. These secondary hairs are cutinized and supersede the evanescent primary ones.

In the ferns, cortical hairs occur in at least two genera of the Vittariaceae. *Hecistopteris pumila* has a peculiar epidermis in which the hairless cells slough off early. The cortical cells frequently bulge, cut off the bulge with a wall, and apparently the cell thus formed becomes a hair (*Fig. 6*). A similar cortical origin of hairs, often more than one from a cell, is frequently observed in *Vittaria elongata* (*Fig. 7*). There is a visible contrast between these younger cortical hairs and the old, yellow, epidermal ones.

CELL WALL STRUCTURE IN ROOT HAIRS

Cormack (1949, 1962) summarizes a great deal of the work on angiosperm root hair walls. Although the primary growth of the hair is at the tip, wall growth takes place over the whole cell surface, even when the growth in length has ceased. The wall consists of an inner, primarily cellulose layer and a layer largely made up of pectins, calcium pectate (in hardened walls), hemicelluloses, and proteins with imbedded cellulose microfibrils. In at least many cases there is a thin cuticle, but perhaps in young root hair walls only the fatty acid precursors of cutin are present. In some cases the root hair is surrounded by a mucilage sheath of pectin-like substances, which it is thought are extruded along plasmodesmata through pits in the wall. Lignified root hair walls have been reported in a few cases. Callose may be present in root hair tips.

The structure of fern root hairs is extremely variable. As noted above, the wall is usually stained brown, In some ferns root hair growth seems to be determinate. The tips are stiff and unbending and the walls are uniformly colored. The species of *Pyrrosia* studied had very short, wide, uniformly brown hairs with narrow, thick-walled tips (*Fig. 8*). Although it varies from group to group, the one feature that perhaps distinguishes a "rhizoid" type of trichome, whether it is on a root, a rhizome, or a gametophyte, is its flexible, mucilaginous growing tip (Cormack, 1949, 1962), a feature that seems adapted to a hydrotropic search for moisture. Schwarz (1883) reports rhizoids 18 mm long in *Marchantia* (a hepatic), and Priestley, Scott, and Harrison (1964) report that root hairs sometimes reach over an inch in length. The growing "rhizoid" type of hair tip is grayer than the mature lower portion and its outline usually has a fluid appearance. A film of mucigel excreted by the roots, which fills the space between the cell walls and mineral soil particles and provides an intimate contact for the absorption of water and nutrient ions, has recently been described in reports of electron microscope studies (Jenny and Grossenbacher, 1963).

Spiral deposits sometimes can be detected in fern root hair walls, and the hairs themselves are frequently somewhat spiral in form. Meinecke (1894) reported conspicuous spiral thickenings in the hairs of some orchid aerial roots.

Some Hymenophyllaceae hairs, at least in *Hymenophyllum laciniosum* and *Trichomanes membranaceum,* have a kind of faintly banded wall structure not seen in other ferns (*Fig. 9*). The entire hair in these species has a telescoped appearance, as if it had grown by repeatedly bursting through a circular tip and extending the wall from within. These root hair (or rhizoid) tips taper and are somewhat thickened at the end, a not uncommon occurrence (Strugger, 1930).

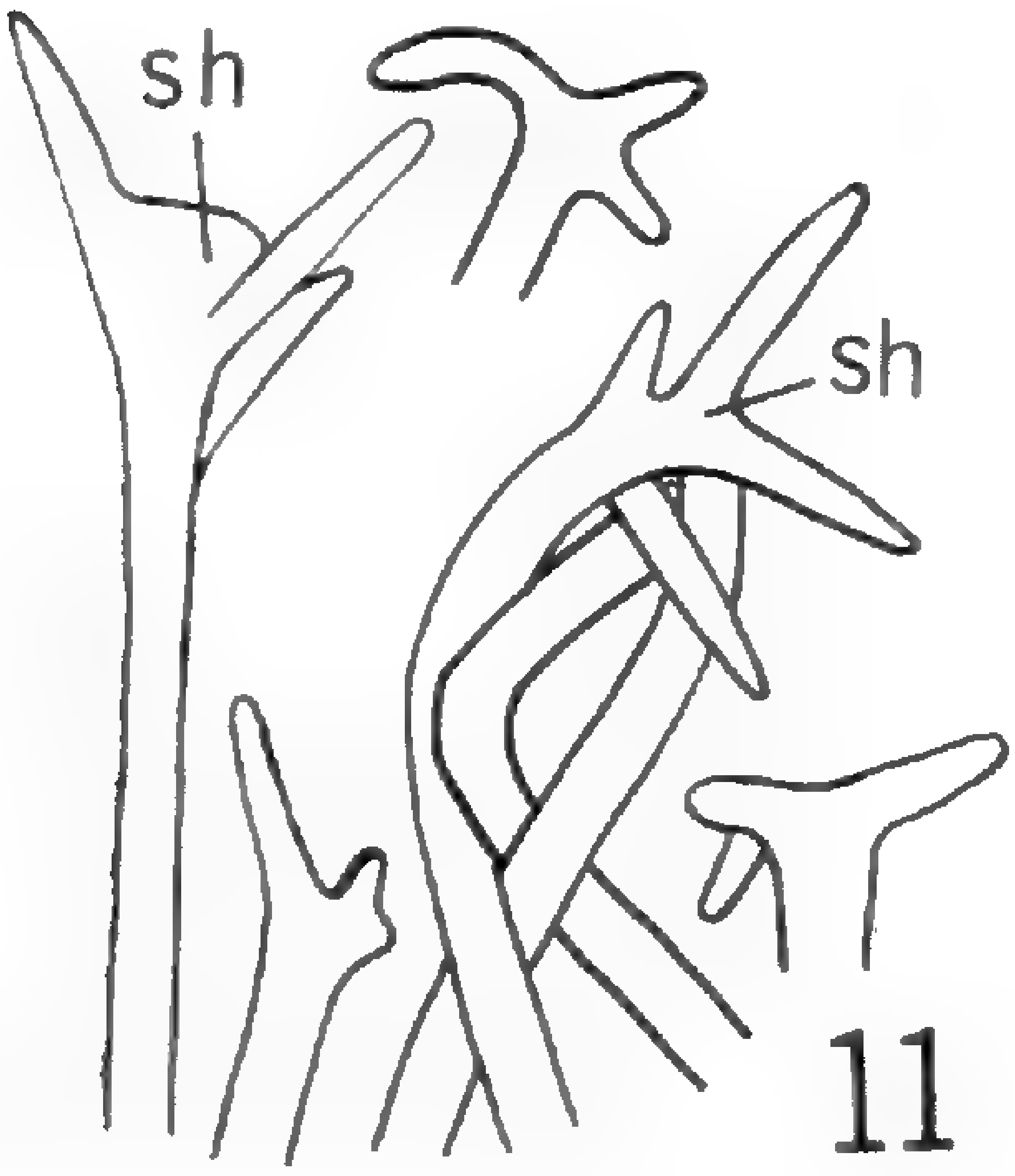
Unlike most angiosperm root hairs, fern root hairs usually persist for a very long time. Apparently the walls are made of more resistant materials than are those of nearly all angiosperm root hairs. The length of life of a root hair varies and is apparently largely genetically determined.

Many fern roots seem to be capable of extreme dormancy. The apical meristems and cortices of the roots become sclerified and die, protecting the living but dormant stele and its meristematic endodermis.

The anchorage function of root hairs seems very important in one case. The climbing *Polypodium vacciniifolium* puts out roots apparently as a thigmotropic response. When a root touches a substrate it puts out root hairs, some quite huge, which cement themselves to the contours of the substrate. Apparently even the rootcap in this plant sometimes develops hairs. Hairs at the extreme tips of roots have been reported before by Richardson (1953), Cowles (1911), and others.

MULTIPLE HAIRS

The twin root hairs on certain angiosperms like Eriocaulaceae and Juncaceae reported by Van Tieghem (1887) came from two trichoblasts with the same mother cell. In *Distichia* (Juncaceae) they are fused for half their length so that they look like a single forked hair. Friesen (1929) was able to produce branched and



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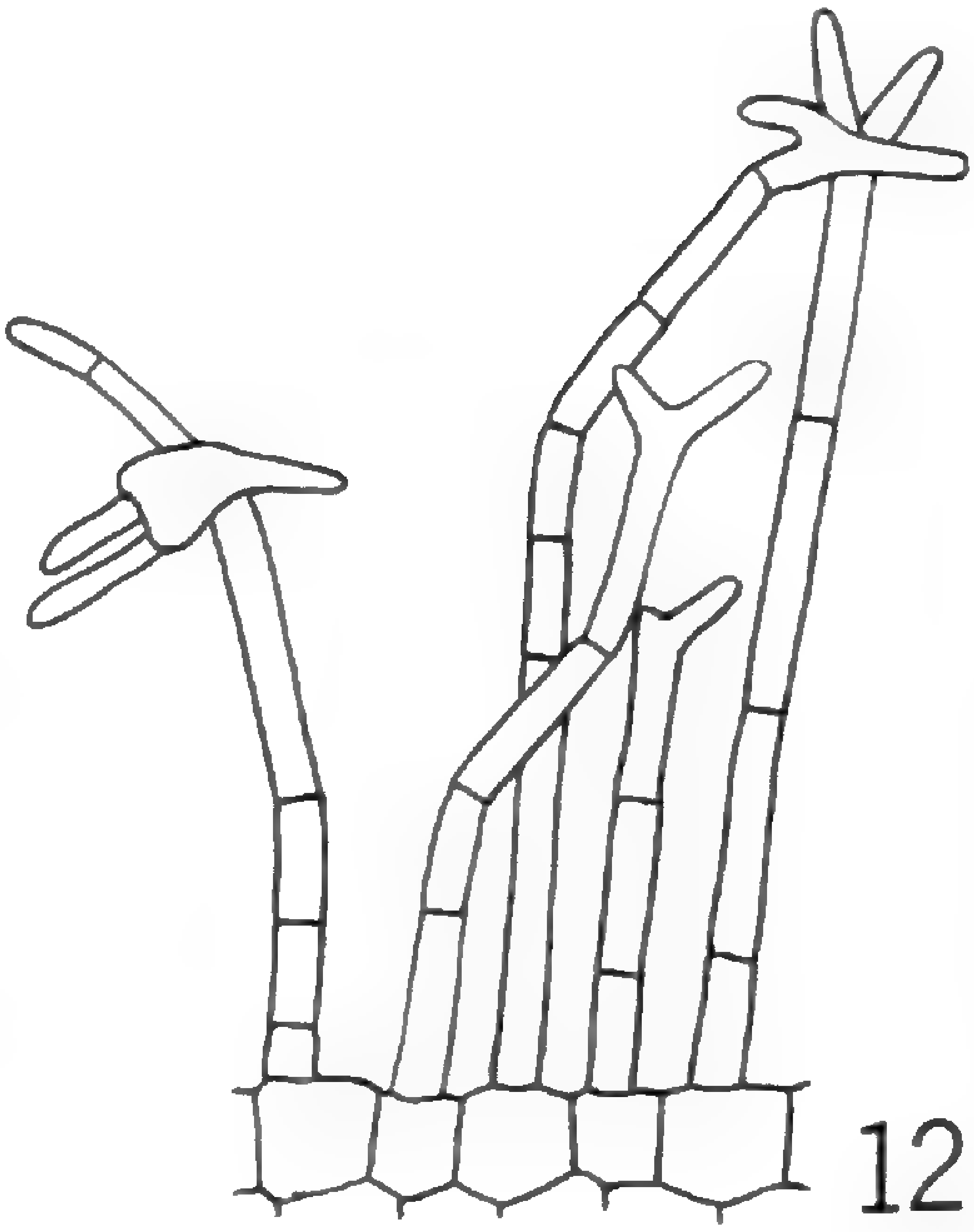

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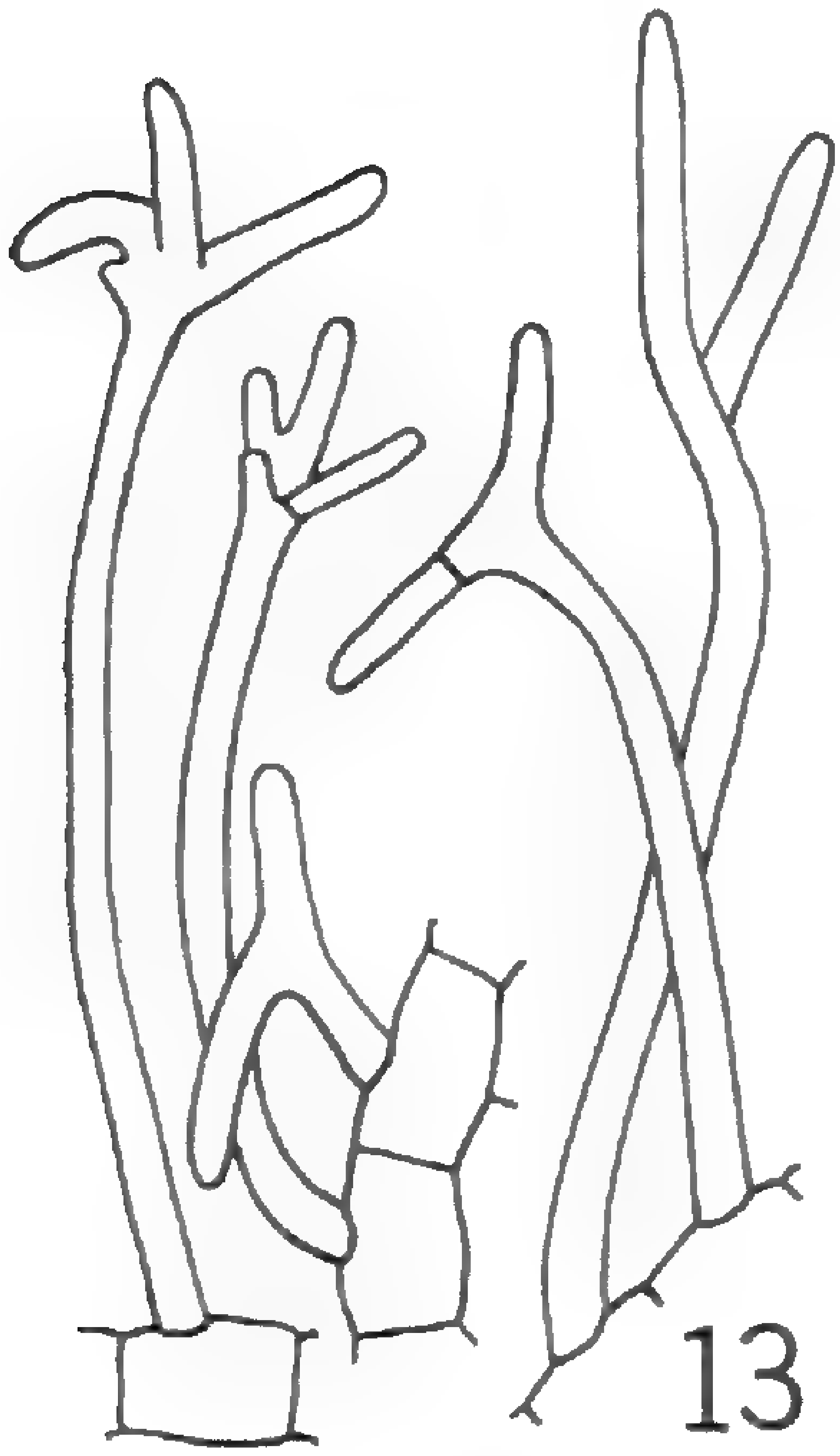

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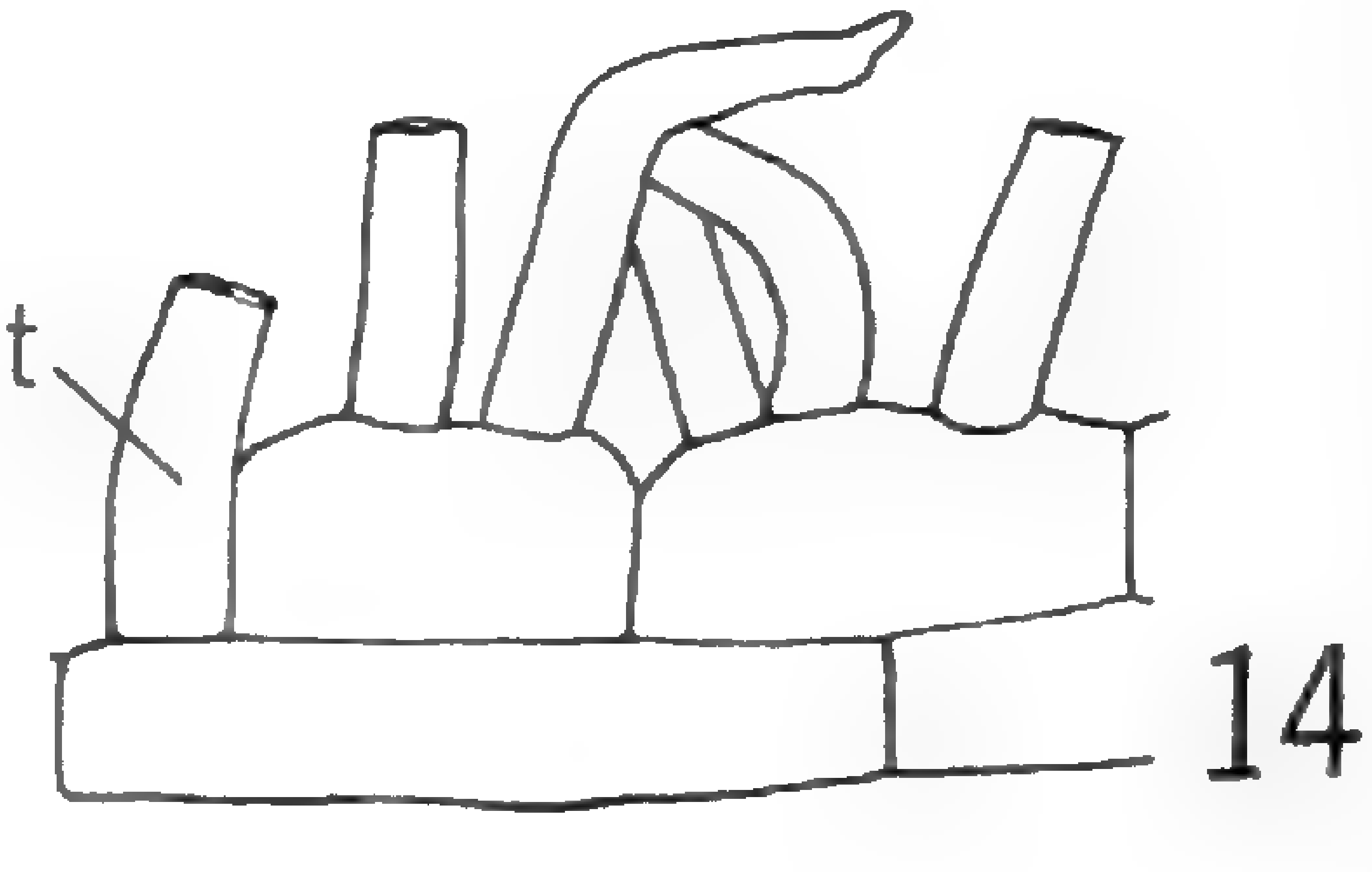

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Fig. 11. Branched hairs from the roots of Hymenophyllum laciniosum. Fig. 12. Same, from the rhizome of Trichomanes membranaceum. Fig. 13. Branched rhizoids from a hymenophyllaceous gametophyte. Fig. 14. Anomalous development of root hairs in Hecistopteris pumila. The abbreviations are: sh = young stellate hair, t = trichoblast.

multiple root hairs on wheat by treatment with phenylurethane, but I find no reports of trichoblasts that regularly produce several hairs in any vascular plant.

My study revealed several interesting cases of multiple hairs from a single trichoblast. In *Antrophyum* and in one species of *Gleichenia* many twin hairs come from the same cell, although the great majority of the hairs are solitary. The cortical cells of *Vittaria elongata* are apparently just as apt to produce two or three hairs as one (*Fig. 7*), and this may also be true in *Hecistopteris. Trichomanes membranaceum* frequently produces twin rhizoids on the epidermal cells of the rhizome.

The most amazing case of multiple hairs occurs in the root epidermal cells of *Hecistopteris pumila* (*Fig. 10*). The only limit seems to be the number of hairs that can crowd onto the surface of the trichoblast. This is one of the plants with trichoblasts interspersed with hairless cells. The hairless cells collapse early and the trichoblasts stand out as little blisters with tufts of hair.

BRANCHING OF ROOT HAIRS

Root hair branching, especially under experimental conditions, has been reported so frequently that I shall not attempt to list references. Apparently this has never been reported to be characteristic of a species, but it appears to be so in *Platycerium* and in other ferns whose root hairs form a pseudoparenchyma and in *Platycerium* and perhaps others where the production of stellate root hairs appears to be a genetically fixed phenomenon of old age. In *Platycerium* the old roots sometimes have fluffy masses of stellate and filamentous hairs intermixed. During this study branching was observed in the root hairs of *Trichomanes dentatum, Angiopteris, Elaphoglossum, Histiopteris, Lygodium, Ctenopteris, Blechnum, Doryopteris, Cyrtomium,* and *Polypodium. Hymenophyllum laciniosum* hairs on older roots are frequently branched (*Fig. 11*) as are the rhizoids on *Trichomanes membranaceum* rhizomes (*Fig. 12*). The branching of the hairs on Hymenophyllaceae sporophytes is similar to that of the rhizoids of certain Hymenophyllaceae gametophytes (*Fig. 13*).

CROSS WALLS OF THE HAIRS

Because of heavy deposits of dark material, it is usually difficult to see septa or nuclei in hairs. In general there are no cross walls, but there is always a chance that a few may be overlooked. The root hairs of the Marattiaceae have long been known to be septate. In the Vittariaceae both *Antrophyum* and *Hecistopteris* separate the cytoplasm of the trichoblast from that of the root hairs by a septum at the base of the hair. This is easy to see in *Antrophyum* because of the abrupt transition from the gray trichoblast wall to the brown root hair wall at the septum. I cannot say positively that septa are universal at the base of the hairs in *Hecistopteris*. It may be that short trichoblasts with single hairs have no septa (*Fig. 14*). In these two species of Vittariaceae the axes involved probably all ended in rootcaps, although the caps were not always observed.

Trichomanes membranaceum in the Hymenophyllaceae has no rootcaps. The cytoplasm of the rhizoids on the rhizome is separated from the cytoplasm of the trichoblasts by a septum. Many of these rhizoids appear to be non-septate except for this basal wall, but there are also numerous septate rhizoids associated with the non-septate ones. *Hymenophyllum laciniosum* regularly has septa in many of its root hairs, but there is no sharp distinction in size and shape between septate and non-septate hairs. The septa sometimes are obvious, but some are difficult to see because of the dark deposits in the walls. For the same reason it is impossible to ascertain whether or not there is a nucleus in each root hair cell. Septate root hairs occur with high frequency in *Gleichenia*, and occasional septa were observed in the root hairs of most of the ferns studied. These were no doubt often formed over the retracted cytoplasm where the root hair tip was dying back, as described by Haberlandt (1909).

The rhizoids on the rhizomes of *Psilotum* are cut off at the base by a septum. *Psilotum triquetrum* [= *P. nudum*] rhizoids were reported to be two-celled by Solms-Laubach (1884). I can confirm that they have a short basal cell and a long root-hair-like terminal cell. The gametophytic rhizoids, however, as illustrated by Bierhorst (1953), are made up of two or three more or less equal cells.

ROOT HAIR DIMORPHISM

The question frequently arose during this study whether a fern might not have two kinds of trichomes on its roots. In *Rumohra adiantiformis* clusters of scales grow out on the bases of the roots for a short distance away from their points of origin on the rhizome, forming a sort of involucre. This occurs less noticeably in several other species, but I was unable to verify the presence of scales farther out toward the root tip, although in several instances a lone scale or two seemed to be growing in place.

Septate hairs with a strong basal curvature frequently were seen on *Trichomanes membranaceum* rhizomes mixed with straight, narrow, pointed hairs and the usual rhizoid type of hair. Strongly curved hairs are a common occurrence in vascular plants, but this survey did not show that they characterized the roots of any of the species studied, although they were occasionally present. However, there are several cases in which there appear to be both "rhizoidal" hairs (with flexible tips) and straight, narrow, septate hairs. *Angiopteris evecta* and *Osmunda claytoniana* and possibly *Hymenophyllum laciniosum* and the species of *Gleichenia* studied have this dimorphism.

The most striking instance of dimorphism is in the root hairs of *Platycerium*. Since these form a tight pseudoparenchyma pressed against the lower surfaces of the appressed scale fronds on which they grow, it seemed possible that the stellate hairs apparently formed in this pseudoparenchyma were actually pulled off the scale fronds. However, this idea became questionable when stellate hairs were found on roots growing through the mesophyll of the scale fronds. It seems probably that the roots invade the scale fronds while the latter are still alive! In addition, great masses of stellate hairs were found on roots in such quantities that they could only have grown there. The roots had rootcaps, and so had not undergone a transition into stem tissue. (*Platycerium* sometimes produces buds on its roots.) Perhaps these stellate hairs, as much as the usual filamentous type, serve for water absorption. Winkler (1964) reports that *Miconia* and *Medinella* in the Melastomataceae produce stellate trichomes on their leaves that absorb a great deal of water. Although there is a question whether the fluffy masses of stellate and filamentous hairs on *Platycerium* roots absorb water, they must help to retain it by capillarity. Popesco (1926) reported that older root hairs do not absorb water and that the surface of the young root is as permeable as even the young root hairs. It seems likely that the unsclerified live tips of mature fern root hairs are always able to absorb water wherever they find enough to keep them alive.

Degeneration in rhizoid-type hairs appears to have occurred frequently in the course of vascular plant evolution. Not all plants have root hairs. The Ophioglossales among the ferns, the date palm (Went & Darley, 1953), certain water plants, some conifers (Plaut, 1910), and some other plants have no root hairs. Hairs are produced so infrequently on the roots of some healthy ferns that it seems that they are present merely as evolutionary relics. Conversely, rootcaps may be lost while rhizoids persist, as evidently occurred in a subgenus of *Trichomanes*. The minute secondary lateral axes in *Quercus rubra* L. (*Q. borealis* var. *maxima* (Marsh.) Sarg.), which bear most of the absorptive trichomes, are reported not to have rootcaps (Richardson, 1953). As Eames (1936) has pointed out, loss mutations play a major role in the course of evolution.

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The Introduction and Establishment of Ceratopteris in Texas

HERBERT H. HANNEN

Very recently Mr. C. V. Morton (THIS JOURNAL **57:** 13–14. 1967) has reported the occurrence of *Ceratopteris thalictroides* (L.) Brongn. in the San Marcos River as a species new to the Texas flora. This species was introduced into Spring Lake, San Marcos, Texas, in 1963 by Mr. Leo Osborne, who was at that time manager of the Texas Aquatic Plants Company, San Marcos, Texas.

During the summer of 1963, Dr. R. Thacher Gary, Southwest Texas State University, observed one small specimen in the San Marcos River below Spring Lake Dam. From September, 1963 through May, 1965, I undertook an extensive study of the macrophyte community in the first 650 meters of the headwaters reach of the River. During this time I did not find one specimen of *Ceratopteris.* The specimen reported by Mr. Morton was collected June 7, 1966; the species was reported as being common in the shady part of the River. September, 1967, was the first time I visited Spring Lake and the River after 1965. At that time the species was well established in Spring Lake, in the headwaters reach of the river, and for several river miles downstream. The species survived a flood in January 1968, during which time the river inundated its banks and the river bed was scoured.

I wish to thank Dr. D. S. Correll, Texas Research Foundation, Renner, Texas, for the identification of this species.

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Actino-plectostely, a Complex New Stelar Pattern in Selaginella

JOHN T. MICKEL AND ROBERT L. HELLWIG

The genus *Selaginella* has been a popular subject of study for over 100 years. Its unique and still enigmatic organ, the rhizophore, has attracted many investigators; aspects of the plants' reproduction have been studied by other workers. Since heterospory represents a major step in the evolution of the seed, *Selaginella* has been a favorite example in plant morphology courses.

Many papers have been published on the genus. Although several general morphological and anatomical studies have been made (Hieronymus, 1902; Harvey-Gibson, 1894; Steel, 1923; Wardlaw, 1925; Zamora, 1960), very few of the approximately 700 species have been thoroughly investigated. Recent authors have discussed its spores (A. Tryon, 1949; Hellwig, 1969), sporangial arrangement (Horner and Arnott, 1963), and the root and rhizophore in light of new evidence (Webster and Steeves, 1963, 1964). Certain other morphological features have been pointed out in the taxonomic treatments of Alston (1955) and R. Tryon (1955).

Several stelar types have been described in the genus (Harvey-Gibson, 1894). By far the most common types are the ribbon-shaped monostele and the bistelic type (two separate round protosteles). More elaborate stelar patterns have been recognized: (1) three or more stelar ribbons in all stem axes; (2) two ribbons in the rhizome and one in the erect stem with a ventral round bundle; and (3) a solenostelic rhizome and polystelic erect stem.

During a course in the biology of tropical pteridophytes in Costa Rica for the Organization for Tropical Studies (Mickel, 1967), the senior author preserved material of *Selaginella exaltata* (Kunze) Spring, a species notable for its large size (*Fig. 1*). Plants may reach more than a meter in height, with megaspores up to 1.5 mm in diameter. There is no creeping rhizome. The stem is erect, reaching a diameter of 5 mm in the lower internodes and 8 mm in the swollen "nodes" (sites of stem ramification), and is supported by several rhizophores up to 35 cm long and 2 mm in diameter.

FIG. 1. BOTANIST HOLDING SELAGINELLA EXALTATA, OSA PENINSULA, COSTA RICA.

The plant is heterophyllous, "articulate" at the nodes, and has frond-like primary branches. Examination of the stem anatomy of typical specimens of *S. exaltata* has revealed a previously unreported stelar pattern, which is described in this paper.

Hand sections were made from material preserved in FAA and from dried specimens soaked in warm water and detergent. The erect stem is roughly circular in outline with a shallow groove on the dorsal side along which the four ranks of leaves are arranged (*Fig. 2*). The outer cortex is composed of sclerenchyma; the parenchyma cells of the inner cortex are thin-walled. As in other species of *Selaginella*, the stele is separated from the cortex by a lacuna which is traversed by trabeculae.

The stele of the erect main stem is a sort of three-lobed plectostele, which we have termed an "actino-plectostele." Such a stelar type has not, to our knowledge, been heretofore reported in any plant. There are two previous references to the vascular anatomy of *S. exaltata*, both very brief. Hieronymus (1900) reported the stele as having "2–3 Hydromkörpern" (xylem bodies), and McAlpin (1967) said its stele was composed of "several irregular traces."

In transverse section the xylem is found in several patches, each surrounded by phloem. Areas of sclerenchyma also occur between xylem patches. The stele itself is basically T-shaped in transverse view, a pattern that is repeated in the primary and secondary branches. The stele is always oriented with the bottom of the "T" toward the ventral side.

The stele undergoes complex changes in xylem configuration within a single internode, the most dramatic of which are made near the node. Generally the two dorsal arms of the "T" have two and three (or more) bundles of xylem (*Figs. 5–13*). The side with three or more bundles (two long and one to three short) will produce the next branch. The lateral groove in that arm of the stele becomes the major groove in the stele of the primary branch (*Fig. 3*). The center bundle contributes to the top of the omega-shaped branch trace, and the two larger bundles to the sides (*Fig. 14*). The base of the "T" also contributes to the branch

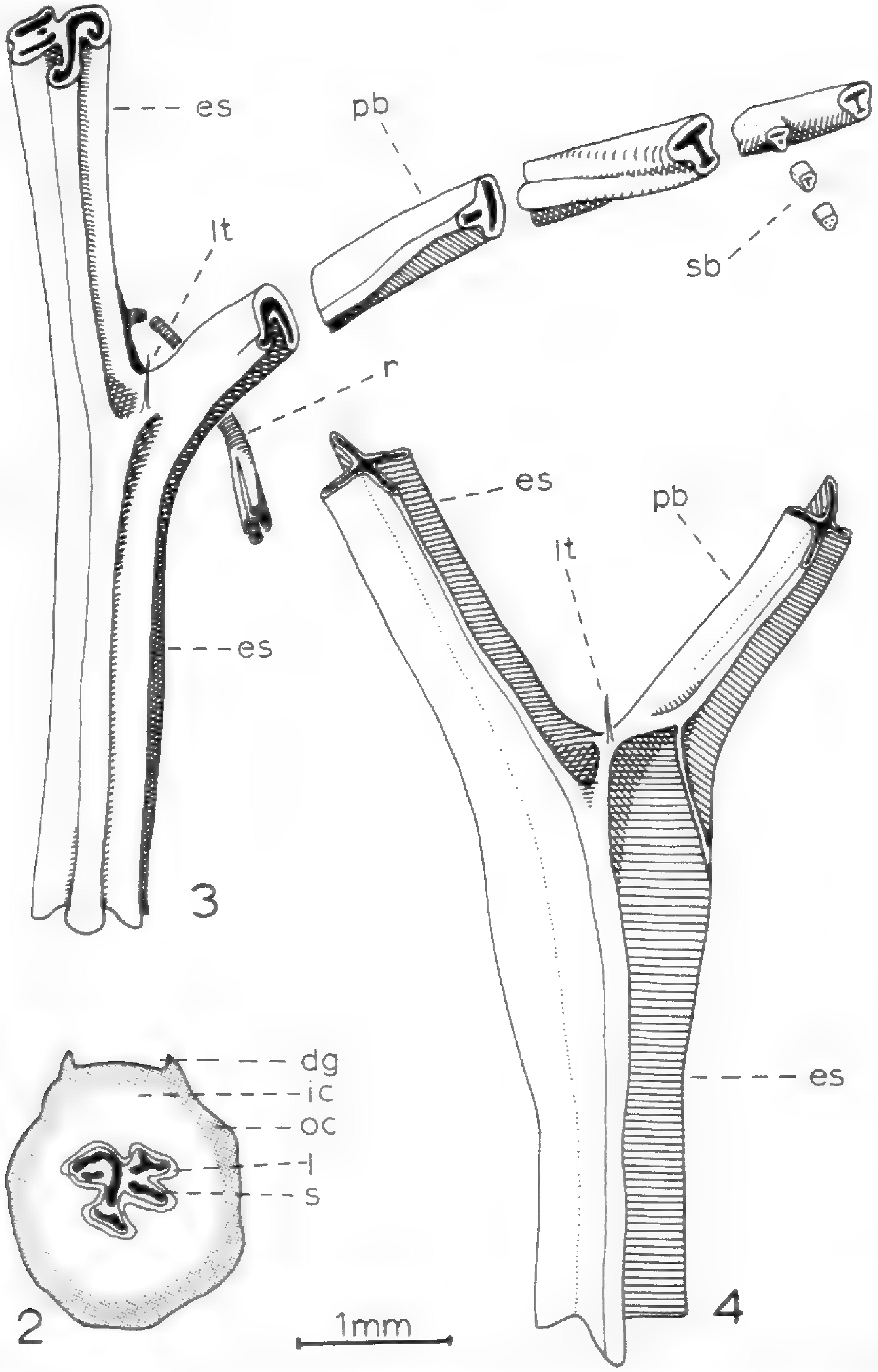


FIG. 2. DIAGRAMMATIC TRANSVERSE SECTION OF ERECT STEM OF S. EXALTATA. FIG. 3. VENTRAL VIEW OF STELE OF S. EXALTATA. FIG. 4. VENTRAL VIEW OF STELE OF LARGE VENEZUELAN SELAGINELLA.

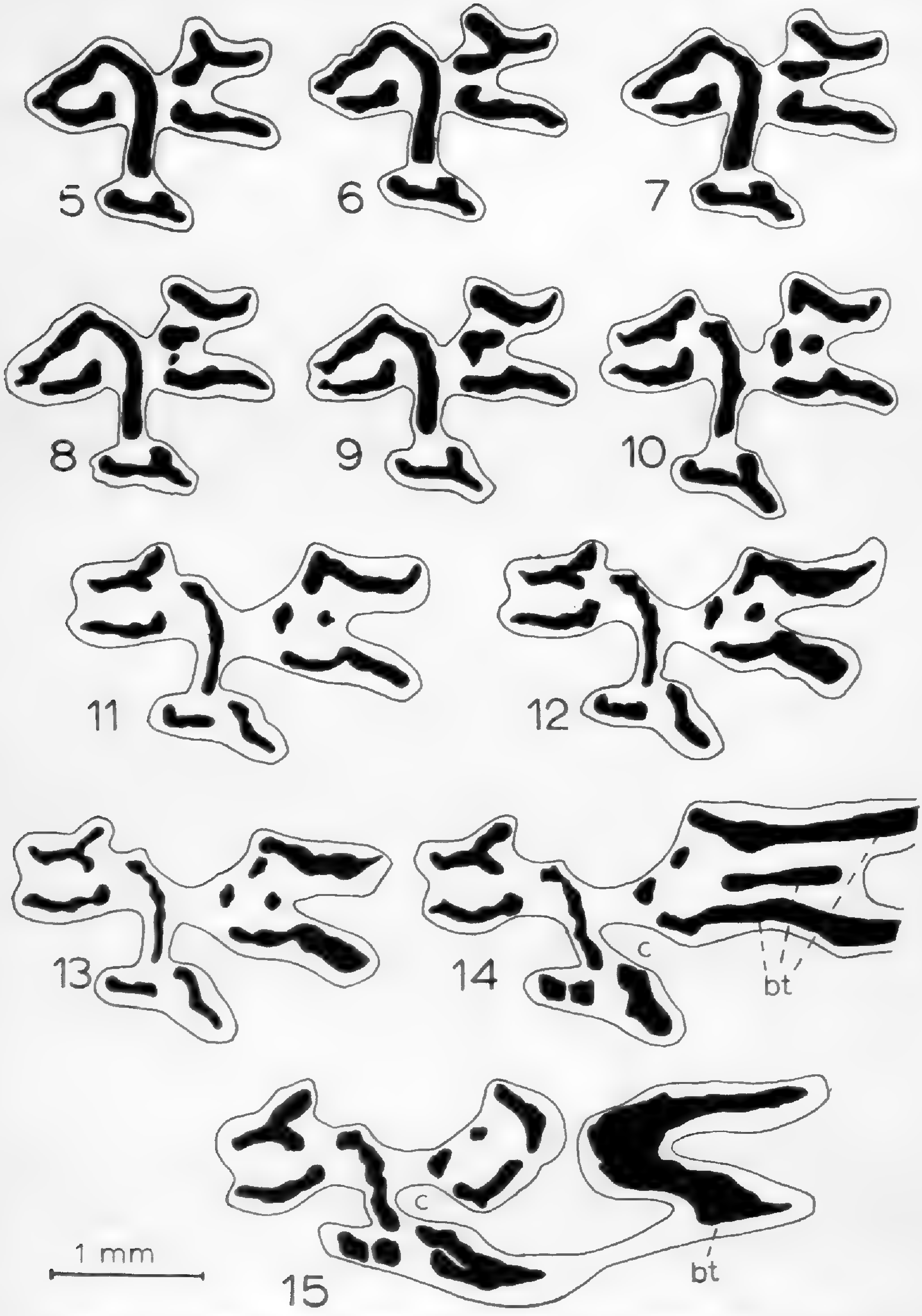
THE ABBREVIATIONS ARE: dg = DORSAL GROOVE, es = ERECT STEM, ic = PARENCHYMATOUS INNER CORTEX, l = LACUNA, lt = AXILLARY LEAF TRACE, oc = SCLERENCHYMATOUS OUTER CORTEX, pb = PRIMARY BRANCH, r = RHIZOPHORE, s = STELE, sb = SECONDARY BRANCH. XYLEM IS BLACK.

trace, although separately (*Figs. 3, 15, 16*). As this vascular tissue passes toward the branch trace, a trace is given off to the axillary leaf (*Fig. 3*). Above the node three xylem bundles appear in the other dorsal arm of the "T" (*Figs. 18–29*); the side that just produced a branch has two. Branches are produced alternately from the two sides.

After the branch trace is given off, the bundles of the stelar arm that contributed to the branch trace form a ring (*Figs. 15, 16*), which fuses with a portion of the xylem bundle at the base of the "T" (*Figs. 16, 17*). The ring opens and gives off the rhizophore trace (*Fig. 16*). The rhizophore trace arises from the stem stele about 1 mm above the branch trace. The rhizophore trace moves slightly downward through the cortex and emerges from the stem at almost the same level as the branch.

Between the middle of one internode and the middle of the next internode above, two portions of the cortex are engulfed by the stele. These portions of the cortex are surrounded by lacunae so they remain isolated from the stele. In the ventral case the ingested cortex is later released (*Figs. 15–19*). In the dorsal one it divides into two, one of which is released whereas the other diminishes in size and disappears (*Figs. 18–28*).

Following the primary branch trace as it leaves the stem stele, the trace appears as a long omega (*Fig. 30*). This quickly shortens and becomes somewhat S-shaped as it leaves the main stem and enters the branch (*Fig. 31*). The large opening is directed downward. A piece of the short tail breaks off and moves to reattach near the middle (*Figs. 32–34*). The end which lost that piece separates and moves over to the middle, forming a disjunct "T" or mushroom-shaped stele (*Figs. 35, 36*). The "T" lies on its side because it is always oriented so that the bar is parallel to the stem's dorsal groove, which is lateral at first. Torsion as the plant grows may twist the frond-like branch into a more horizontal plane (*Fig. 1*). This "T" form is attained in the first centimeter of the primary branch and is maintained for some distance; later the basal lobes become more elongated, and the stalk of the "T" fuses with the dorsal bar (*Fig. 37*).



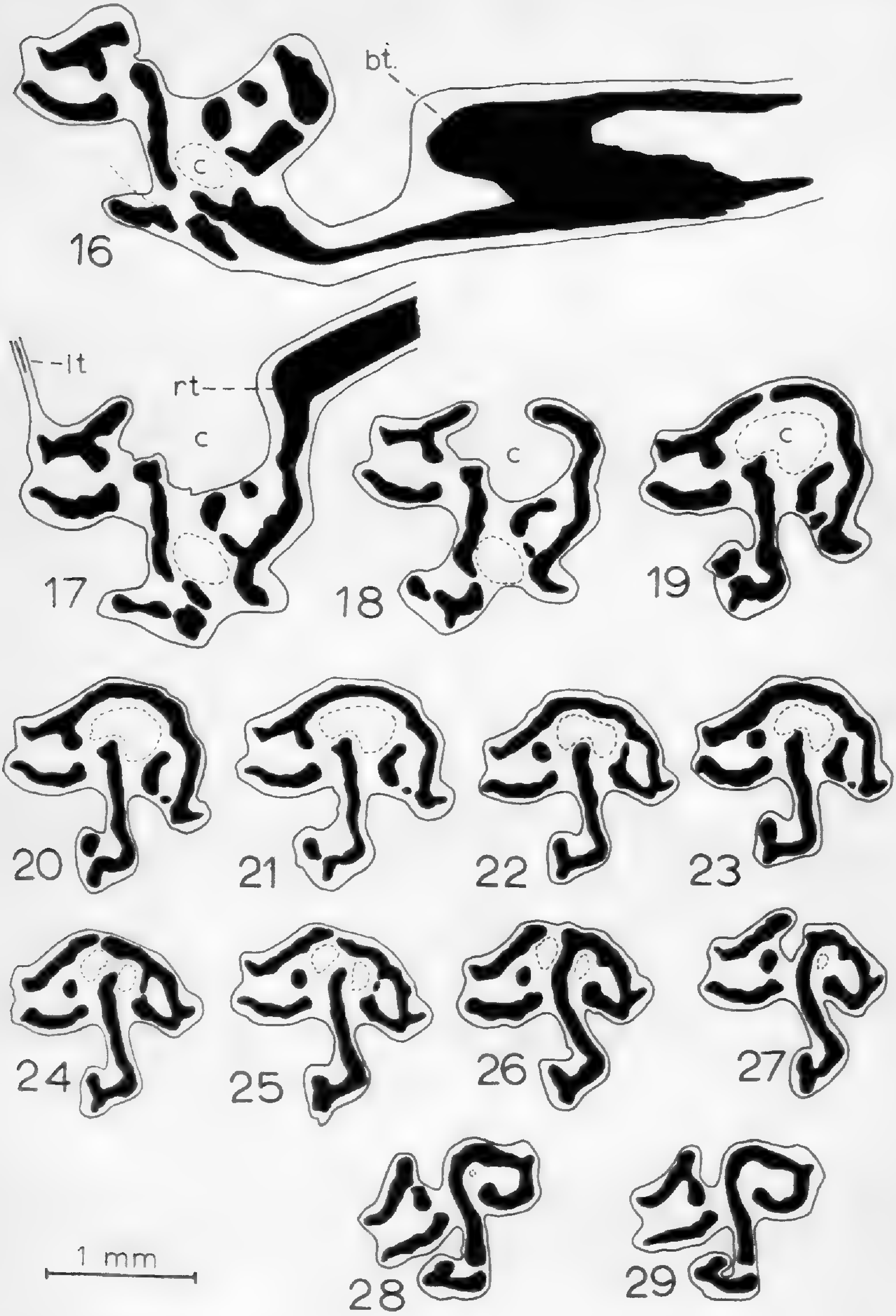
Figs. 5–15. Serial transverse sections of erect stem stele of S. exaltata showing stelar changes from one internode to the next higher internode. The abbreviations are: bt = branch trace, c = cortex, lt = leaf trace, rt = rhizophore trace. Xylem is black.

As the primary branch gives off each secondary branch, the dorsal and ventral bars of the "T" elongate to one side to contribute to the secondary branch trace (*Figs. 38–41*). The secondary branch trace is C-shaped at first, becoming a ribbon and a round bundle as it passes into the secondary branch (*Figs. 40–43*). Soon the dot fuses with the ribbon to form a "T" (*Fig. 44*). As the branch diminishes in size, the bar (ribbon) divides in two; the stele then holds three round xylem bundles (*Figs. 45, 46*).

The stele of the rhizophore arises from the stem stele as a small, reniform protostele (*Fig. 47*). It soon changes to an oval protostele, becomes medullated, and breaks to form an omega (*Figs. 48–50*). As it leaves the cortex of the main stem, the xylem within the rhizophore stele breaks up, and the stele itself soon divides into four separate steles, each with its own lacuna (*Figs. 51, 52*). One or two of the steles may further divide, but four lacunae seem to remain (*Fig. 53*). There are five or six steles for most of the length of the rhizophore.

Shortly before the rhizophore forks, the steles proliferate further. Each lacuna contains two or three separate steles (*Fig. 54*), and so when the rhizophore divides, it has 10–12 steles (*Fig. 55*). The rhizophore divides dichotomously several times within a short distance, with each stele entering a root (*Fig. 56*). Previous workers have reported the rhizophore as monostelic. The polystelic condition here may be correlated with its large diameter, although *S. lobbii* with a rhizophore diameter up to 3 mm is monostelic (T. R. Webster, pers. comm.). Further division of each root is accompanied by division of the single protostele. Each root has a lacuna around its stele, as reported by Webster and Steeves (1963) for *S. densa*.

The distinctive stem anatomy of *Selaginella exaltata* makes it especially apparent that the rhizophore anatomy, although polystelic, is essentially that of the root. The fact that rhizophores may be transformed into leafy shoots under certain experimental conditions (Williams, 1938) is shallow evidence for calling the rhizophore a stem rather than a root. The angle meristem from which it is derived probably has the potential to develop into a



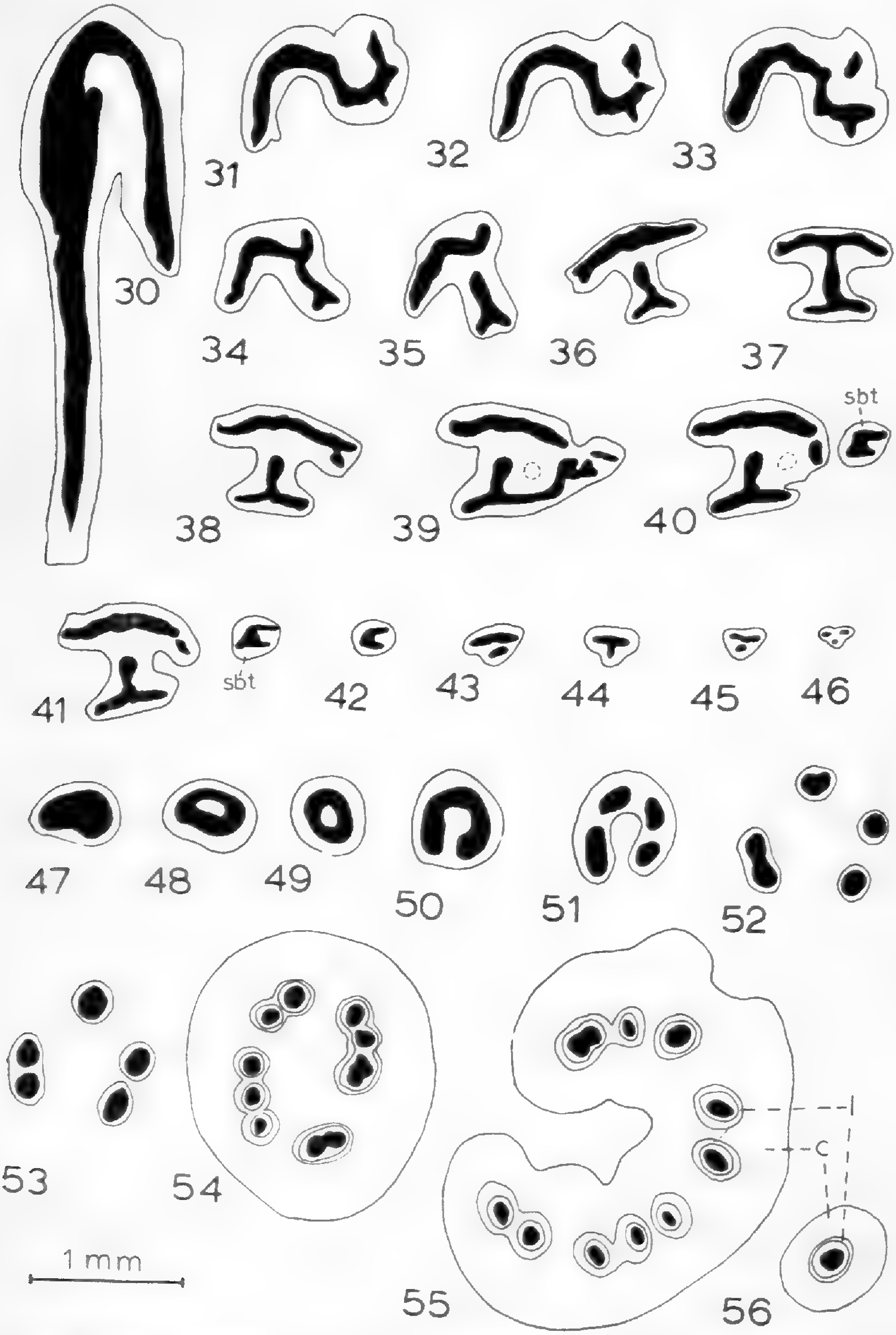
Figs. 16–29. Serial transverse sections of erect stem stele of S. exaltata showing stelar changes from one internode to the next higher internode. For abbreviations see Plate 14. Dashed line indicates lacuna with trabeculae; Xylem is black.

stem or a rhizophore, but it seems to us more reasonable to view the rhizophore as a root, based on its normal behavior.

The stelar anatomy of *S. exaltata* is the most complex presently known in the genus. Nearly all other steles in the genus are ribbon-shaped or round. *Selaginella uncinata* has a ribbon and a "ventral round bundle," corresponding to the secondary branch traces in *S. exaltata*. *Selaginella braunii* has a T-shaped monostele (Wardlaw, 1925). Other variations previously described (Harvey-Gibson, 1894) are quite distinct from that of *S. exaltata*.

The ribbon-shaped stele is the common one for the homophyllous species and for the non-articulate heterophyllous species. We would postulate that the ribbon-shaped monostele is the primitive one in the genus, being found in the least differentiated groups. McAlpin (1967) found that in 18 Costa Rican heterophyllous species the non-articulate species had ribbon-shaped monosteles, the articulate ones were distelic, and *S. exaltata* was distinct from these. Subsequent to our work with S. *exaltata*, we made a survey of stelar patterns in *Selaginella* species available to us. We have verified McAlpin's findings and have made observations on 26 additional Mexican and Central American heterophyllous species. All the non-articulate species examined are monostelic; the articulate species are mostly distelic; *S. articulata* is tristelic. The complex stelar system of *S. exaltata* resembles neither the ribbon nor polystelic types, although its spores Hellwig, 1969) and external morphology relate it to the polystelic types.

The remarkable stelar structure described here is not entirely correlated with the plant's large size. We have been privileged to see a specimen of an even larger species, apparently undescribed, from Venezuela (*Steyermark 95418*), and we thank Dr. David B. Lellinger of the Smithsonian Institution for sending us dried stem material of this species. The lower stem has a diameter of 8–10 mm in the internodes, and apparently is not swollen at the nodes. In spite of the plant's great size, it has less complex stelar anatomy than does *S. exaltata*. The xylem is a solid X-shaped strand (*Fig. 4*); the stele is similarly shaped. The slender arms of xylem are



Figs. 30–56. Serial transverse sections of stelar anatomy of *S. exaltata*. Figs. 30–37. Primary branch. Figs. 38–46. Secondary branch and its origin from primary branch. Figs. 47–53. Rhizophore stele. Figs. 54–55. Entire rhizophore. Fig. 56. Entire root. The abbreviations are: c = cortex, l = lacuna, sbt = secondary branch trace. Xylem is black.

surrounded by phloem. Small patches of sclerenchyma are found in the angles of the stele.

Primary branches are formed in much the same way as in *S. exaltata*, although with simpler stelar changes. The "X" pattern is continued. The ventral arm of xylem in the main stem contributes a separate band to the branch, as in the former species, with the trace of the axillary leaf arising from the bridge (*Fig. 4*).

The rhizophore is enormous, 6.5 mm thick, although its internal anatomy is much like that of *S. exaltata* with five individual steles in four lacunae in sections taken 1 cm from the stem.

Further study is required to determine the degree of relationship between this species and *S. exaltata*, but preliminary anatomical study does not suggest close affinity.

This study has shown that the diversity of stelar anatomy in *Selaginella* is much greater than previously thought. New species may be described which will shed further light on stelar evolution in the Lycophyta. Our preliminary examination of various North and Central American species suggests that further anatomical studies in *Selaginella* would be profitable morphologically and taxonomically.

We wish to thank Dr. Nels R. Lersten and Mr. J. Stuart Lassetter for their useful suggestions in the preparation of the manuscript and illustrations.

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Recent Fern Literature

EARLY BRYOLOGICAL LITERATURE, by W. D. Margadant. The Rachel McMasters Miller Hunt Botanical Library, Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213. 277 pp. 1968.—Although "Early Bryological Literature" is primarily a bibliography of publications on the bryophytes published in the early part of the nineteenth century, a number of the authors mentioned and the works treated deal with ferns also, and so this publication will be of value to pteridologists. Among these botanists who published on ferns as well as bryophytes are such well known names as Robert Brown, A. P. de Candolle, Desvaux, Gaudichaud-Beaupré, Reinwardt, Sprengel, and Sturm. This work gives some details of their lives and publications. In addition, the introductory section gives many important details of bibliographic interest—comments on types of paper, methods of printing and binding, format, and a list of bibliographic signs and abbreviations. Of especial interest is a section on the "Collational Formula," in which a new system for indicating signatures is proposed. —C.V.M.

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American Fern Journal

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The Fern Collections in Some European Herbaria, V

C. V. Morton

Florence

The herbarium of the Istituto Botanico of the University of Firenze, is located in Florence (the traditional English "translation" of Firenze) in the region of Tuscany, Italy. In the "Index Herbariorum," the herbarium is stated to contain 3,500,000 specimens, which places it among the largest herbaria in the world. The figure was slightly too large when it was estimated in 1954, but the ca. 400,000 specimens added since that time make it about right now, according to Prof. Moggi. The main part, the "Central Herbarium," was founded in 1842. A young Italian botanist named Filippo Parlatore (1816–1877), then 26 years of age, asked the Grand Duke Leopold II of Tuscany to establish a national herbarium. The Duke agreed and appointed him as the director.

At the beginning there was little material other than Parlatore's own Italian collections, although there were a few old collections that were the property of the Duke. Among these the most notable was a set of the Brazilian plants collected and described by Guiseppe Raddi (1770–1829), and also a set of the bryophytes studied by Raddi. The Brazilian plants were all unlabelled, and so Parlatore set about identifying the plants with the descriptions of Raddi; the present neat labels are in the hand of Parlatore. These Raddi specimens were all correctly named by Parlatore, so far as I observed, but they can not be considered as more than probable isotypes. The holotypes are in the University of Pisa. This may not be true of the bryophytes, which I did not look at. The herbarium also included plants of Egypt collected by Raddi.

Volume 59, No. 3, of the Journal, pp. 89–136, was issued Oct. 8, 1969.

Shortly after the organization of the herbarium the Grand Duke authorized the purchase, at a high cost, of the herbarium and manuscripts of Pietro Antonio Micheli (1679–1737), said by Parlatore to have been called the "Lynx de la Botanique"[1] and the "Précurseur de Linné." Micheli was Parlatore's predecessor by a hundred years, having been director of the botanical garden in Florence in the early part of the eighteenth century. His book "Nova Plantarum Genera" (1729) came between those of Tournefort and Linnaeus on plant genera. His herbarium contained important collections from Petiver, Sherard, Scheuchzer, Targioni, and others. He must have been a prolific worker, and it is too bad that most of his works were never published. His manuscripts, as bound by Parlatore, consist of 71 volumes, mostly in folio; these 46 works are varied, mostly on orchids, grasses and fungi (Agaricales). Almost all of them contain drawings, many in color.

The ancient herbarium of Caesalpinus, made probably between 1543 and 1563, and surely one of the oldest in existence, was one of the treasures of the Pitti Palace in Florence. At Parlatore's request the Grand Duke transferred it to the new herbarium, where Parlatore had it rebound in three large folio volumes bound in red velum. The specimens were firmly glued to sheets of paper and and are still in good condition, I am told. Unlike many old herbaria, that of Caesalpinus was well labelled with the names in Greek, Latin, and Italian by Caesalpinus himself, who even provided it with an index. Parlatore added the equivalent names that were modern for his time. The herbarium is carefully described in T. Caruel's "Illustratio in Hortum Siccum Andreae Caesalpini" (Florence, 1858).

Parlatore was a fine and careful curator, and his work is evident even after a hundred years. His method of pinning the labels around the stems of the specimens and of pinning the specimens to the sheets is still in use today. When I visited Florence in July, 1967,

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[1] A reference to Linceus, one of the Argonauts famed for his sharpness of vision, who gave his name to one of the oldest scientific academies, the Accademia dei Lincei ("Academy of the Lynx-eyed"), founded in Rome in 1603, to which Galileo belonged, and still in existence.

there were two men employed full time in pinning specimens to the sheets. It is actually rather fast and efficient. It might be thought that the pins would have rusted away in over a century, but this has not happened. A few have come out, and I took a few specimens to the preparators for repair, but in general the pins have stood up well. This method does have the advantage over gluing, as pointed out by Parlatore himself, of enabling the student to unmount and turn the specimen over for study when this is necessary or desirable, as it often is in studying ferns, where both surfaces offer important taxonomic characters. Parlatore's carefulness is shown also by his statement that he always asked visiting botanists to annotate the specimens that they studied.

Among the herbaria acquired by Parlatore for the Central Herbarium during his directorship is that of Attilio Zuccagni; 1,500 species of algae from Guiseppe Meneghini; the general herbarium of Eugène Reboul; the algae of Camille Montagne (especially from Ceylon, Australia, and the Friendly Islands, which were studied by Harvey); and the Figari Herbarium, mostly of North Africa, and studied by DeNotaris. Among the almost unique collections are those of Rumphius (1627?–1702), in part the basis of his "Herbarium Amboinense" (1741–1755); these are unfortunately not marked on the labels as being from Rumphius, but can be identified in other ways. A majority may be lost; a catalogue of those once present was published by U. Martelli in his "Le Collezioni di Giorgio Everardo Rumpfi Acquisitate dal Granduca Cosimo III de' Medici, una Volta Esistenti nel Museo di Fisica e Storia Naturale di Firenze" (Florence, 1903). Florence is not alone among European herbaria in having a large number of important early collections that are not clearly identified as to their source. Among the important collections in the Central Herbarium are those assembled by Parlatore himself and his students, which form the basis of his classic "Flora Italiana" (1848–1896), the first five volumes of which were by Parlatore, and the continuing volumes by his student and associate T. Caruel. There is a large set of the Nepal and Indian collections of Nathaniel Wallich and his associates. I think it likely that the set of Hance's Chinese plants is the principal set, for it is the most complete, with fine specimens and full labels in Hance's own hand, and probably should be considered to contain Hance's holotypes; I have not tried to trace how or when these Hance specimens arrived in Florence.

Among the other important collections in the Central Herbarium may be mentioned those of Michaux, some of which are not duplicated in the Michaux Herbarium in Paris, as for example *Botrypus lunarioides* Michx. and *Polypodium elegans* Poir., the holotypes of which are in Florence. The Siberian collections are extensive, and include those of Fischer, Pallas, Ledebour, Szovits, and Maximowicz. Included also are the palms of O. Beccari. An herbarium that must be mentioned is that of Adriano Fiori, who published, with A. Paoletti, a "Flora analitica d'Italia" in four volumes, the voucher specimens being in Florence. There is also an album of plants from Sweden, with specimens collected by Linnaeus, Linnaeus fil., Thunberg, Acharius, and Swartz.

The garden associated with the Istituto is one of the most ancient truly botanical gardens of Europe. It was started in 1545, by the Duke Cosimo de' Medici as the "Giardino dei Semplici" ("Garden of Simples"), which was intended to have medicinal plants, agricultural plants, and ornamentals. The garden was completed in 1557. In its later years it was in the charge of Micheli, mentioned above, and later of Ottaviano Targioni-Tozzetti and A. Zuccagni. Caruel built the greenhouses in the later part of the nineteenth century, and introduced many interesting new useful and ornamental plants. Unfortunately, since the last war it has fallen into desuetude, although it is still used by some students and professors in Florence. It is no longer open to the public, and many of the rare plants have doubtless disappeared. It was never very extensive in area, and being in the center of the city of Florence, it could not be readily enlarged. My account of the garden is taken from F. Fabbri's "L'Orto Botanico di Firenze" (Agricoltura, no. 4, 1963).

THE WEBB HERBARIUM

Joseph Barker Webb was born in Milford, Surrey, England, July 18, 1793. He was educated at Harrow and Oxford, receiving his B.A. in 1815. According to the usual custom in those days for gentlemen finishing their education, he set out on a long series of foreign journies that took him to Sweden in 1816, where he seems to have been impressed by a visit to Linnaeus' house and garden, to Italy in 1818, and to Greece and Asia Minor in 1819. He felt particularly drawn to Italy and to Florence.

Although Webb's primary studies in the university had been in classical philology, his interest in botany increased to become his lifelong vocation, or perhaps avocation might be nearer to the truth. Being a wealthy man, he was able to continue his botanical studies without ever being associated with any academic institution or museum. He knew or corresponded with many of the principal botanists of the time, such as Brongniart, DeCandolle, Pavón, d'Urville, Lagasca, Gaudichaud, St. Hilaire, Adrien de Jussieu, Bory de St. Vincent, and A. Richard. From these he received, by gift or perhaps by purchase in some instances, many valuable collections from all over the world, which are listed by Parlatore.

In 1826 Webb began his trips to Spain and Portugal, which were extended later especially to Madeira and the Canary Islands. During his two years in the Canaries he collected with Lowe and especially with Sabin Berthelot (1794–1880). He recalled later that these were the happiest years of his life. With Berthelot, he wrote and published at his own expense the luxurious folio volumes entitled "Histoire Naturelle des Canaries" between 1835 and 1849.

In his later years Webb lived in Paris, where he died August 31, 1854, at the age of 61. In his will he left his herbarium and library to the Grand Duke Leopold II of Tuscany, as well as his house in Paris. He did not however leave the bulk of his fortune to the Grand Duke. There was some controversy over the jurisdiction of the administration of the will because Webb was an English citizen but his will was drawn up in French and it was in France where he died. It may be that Webb's English heirs also contested the disposal of the herbarium and library, which had a large cash value. In the end the matter was settled in the French courts, and the Grand Duke sent Parlatore to bring the herbarium to Florence, which was done in 1855. The herbarium contained in excess of 90,000 species, many of them of course represented by more than one collection, and required 150 large packing cases.

The herbarium was installed in a separate room in the Istituto Botanico, which was at the time located on the Via Romana. The Istituto was moved to its present location beside the botanical garden on the Via Lamarmora in 1905. The Webb Herbarium has been maintained separately ever since. Ordinarily I am somewhat opposed to having several distinct herbaria maintained in an institution, but in this case I am glad that it has been done. It is convenient to have the old Webb Herbarium kept as it was originally, and not completely reorganized as would be necessary to keep up with taxonomic changes.

The definitive biography of Webb, so far as such a thing exists, is the paper published by Parlatore shortly after the death of Webb, entitled "Elogio di Filippo Barker Webb" (Firenze, 1856). Parlatore knew Webb well, from having lived with him in Florence, and from working with him in Paris on his "Fragmenta Florulae Aethiopico-Aegyptiacae." It appears that Webb assisted G. F. Pritzel, for the latter says in the "Thesaurus" concerning Webb: "ein treuer Freund und Beförderer des Thesaurus literaturae botanicae," a remark perhaps unparalleled in the "Thesaurus," and one which may indicate that Webb supported the work financially. The genus *Webbia* DC. was named for him, and the journal currently published by the Istituto Botanico is called "Webbia," now in its 23rd volume. A short biographical notice on Webb appeared at the beginning of the opening volume (Webbia **1:** 1–4. 1905).

The largest and most important herbarium acquired by Webb was that of René Louiche, more commonly known as René Desfontaines (1750–1833). Desfontaines was long associated with the Jardin des Plantes, Paris, but like many early botanists, especially in France, he maintained a private herbarium, which was sold by his heirs, and which Webb purchased for 6,000 francs, a sizeable sum in those days when one considers that Webb's large house on the Champs Elysées in Paris brought only 7,000 francs on its sale. The basis of Desfontaines' herbarium is naturally his own specimens, collected in the deserts of Algeria.

Tunisia, and Morocco, especially in the Atlas Mountains (1,600 species). The holotypes for the species described in Desfontaines' "Flora Atlantica" are in Paris, but there are duplicates of most of them in the Webb Herbarium. In addition, Desfontaines acquired large numbers of specimens from Bélanger, Gaudichaud, Perrottet, Palisot de Beauvois, Poiteau, Ramon de la Sagra, Clausen, Blanchet, Commerson, Isabelle, Sieber, Robert Brown, and many others. Many of these collections were studied by the elder DeCandolle, who was a pupil of Desfontaines.

Jacques Julien Houttou de Labillardière (1755–1834) was a noted French botanist who accompanied the expedition searching for La Pérouse, whose two ships, "La Boussole" and "La Astrolabe," had been missing since 1788. Another French botanist, Ventenat, was also on this expedition, which set off in September, 1791. With Labillardière making collections at every stop, the ship visited Teneriffe, the Cape of Good Hope, Tasmania (known in those days as Van Diemen's Land) and Australia (known as New Holland at the time). Only a few botanists had collected in Australia prior to this time, notably Robert Brown, and Banks and Solander. Later, Labillardière visited New Caledonia, being perhaps the first botanist to collect there, and the Moluccas, especially Amboina, which had not been visited since the time of Rumphius in the previous century. After a visit to Tongatabu, in the Friendly Islands, he sent seeds of the breadfruit (*Artocarpus incisa*) to Europe for the first time, where the plant was cultivated in the Jardin des Plantes, Paris, and also distributed from there to Mauritius and Cayenne. In 1794 the French were at war and Labillardière's ship, "La Recherche," was captured by the Dutch. Labillardière and Ventenat were seized as prisoners of war and transported to Samarang in Java. After some time, they were released and returned to France in March, 1796. However, their plant collections had been confiscated and were sent to England, where they were turned over to Sir Joseph Banks, then the dominant figure in English botany. It is remarked by Lasègue that Banks was so perturbed over the matter that he would not permit himself even a peek into one box, so that it might never be thought that he had stolen any of Labillardière's and Ventenat's collections (or ideas). The specimens, representing more than 4,000 species, were sent to Paris, and Labillardière spent many years in studying them. The many new species were published in several works, notably the "Novae Hollandiae Plantarum Specimen" (1804–1806 [1807]) and the "Sertum Austrocaledonicum" (1824–1825), the first work describing the very peculiar endemic plants of New Caledonia. After the death of Labillardière in 1834 his herbarium was bought by Webb after vigorous competition by many institutions and persons. It forms one of the most important parts of Webb's herbarium. Labillardière's own collections were carefully selected and labelled, and his types all have his original descriptions in longhand, essentially as they were published, attached to the sheets, often with original drawings also. There is therefore no difficulty in deciding on the holotypes. In addition, Labillardière had acquired other valuable collections, including a large set collected by Commerson in his trip around the world, collections from Sweden and Lapland from Thunberg, and the original herbaria, with the types, of Allioni and Bellardi.

Among the earliest collectors in Peru and Chile were Hipólito Ruiz (1754–1815) and José Antonio Pavón (1754–1844), who were sent by the Spanish government to South America in 1777, with Joseph Dombey (1742–1793) as an assistant botanist. Dombey returned to Europe in 1784, before the others, fortunately as it turned out, for his collections were saved and formed the basis for many new species described particularly by French botanists. His specimens ended up in the Jussieu Herbarium in Paris; duplicates were rather widely distributed, but apparently not to Madrid as would have seemed likely. The main collections of Ruiz and Pavón were at least in large part destroyed by a fire in 1785 and in a shipwreck in 1786. These indefatigable botanists returned to the field, assembled another large collection, and returned to Spain in 1788. Here they worked in Madrid and produced several fine volumes, the "Florae Peruvianae et Chilensis Prodromus" (1794) and the "Flora Peruviana et Chilensis" in three volumes published between 1798 and 1802. Most of the holotypes of Ruiz and Pavón are in Madrid, but some are apparently not there. Ruiz died at the age of 61, but Pavón lived to be 90 and remained active in Madrid for most of his life. It seems that he was very generous, and sometimes gave away all of his collections. Webb met him when he visited Spain in 1826, and Pavón gave (or perhaps sold?) him a large number of his specimens, representing more than 4,000 species. These collections, among the most valuable now in the Webb Herbarium, have never been studied critically, and are not in fact indicated on the sheets as being Ruiz and Pavón collections, although they are recognizable from the handwriting and from indications like "II Exped." Some of these doubtless represent the actual types, although it might not be possible to demonstrate this easily; they are at least available for lectotypes. Ruiz and Pavón did not themselves describe any ferns, and so no holotypes are to be looked for in this group. Some data on Pavón's collections in the Webb Herbarium were given by Pichi-Sermolli in his "Le Collezioni Ceduta de J. Pavón a F. B. Webb e Conservate nell' Herbarium Webbianum" (Nuov. Giorn. Bot. Ital. n. s. 56: 699–701. 1950). Those with localities Peru or Chile or marked "II Exped." are indeed collected by Ruiz and Pavón, but those collected in Guayaquil (marked "Hgl" = Huayaquil) and Quito were collected by Tafalla (an assistant of Ruiz and Pavón), and the very considerable number marked Habana, Puerto Rico, or "N. E." (i.e. Nueva España = Mexico) were collected by Sessé and Moçino..

The collections of Gaudichaud-Beaupré in the Webb Herbarium are very fine. They were made on the trip around the world on the "Uranie," under the command of Captain Louis de Freycinet in 1817–1820. Because of the completeness of the specimens in the Webb Herbarium they should be considered in designating lectotypes for the new species described by Gaudichaud, for sometimes they are superior to those in Paris, and indeed it may be that some species are represented only in the Webb Herbarium. They all have original labels in the bold hand of Gaudichaud. There are also in Firenze specimens from Gaudichaud's much later voyage on the "Bonite." It may be mentioned incidentally here that the species illustrated in Gaudichaud's "Voyage autour du Monde executé pendant les années 1836 et 1837 sur la Corvette La Bonite" are published. Even though they are illustrations only without a corresponding text, they do have enlarged drawings of details; they are "plates with analyses" and so valid under the Code.

Other special herbaria acquired by Webb were those of Philippe Mercier, which included many European plants, of Wydler from Puerto Rico, Berlandier from Mexico, many received from DeCandolle, a special herbarium of the Cape Verde Islands (collections of Bolle, Vogel, and others), an herbarium of Maderia plants, the basis of Lowe's "Novitiae Florae Maderensis et Portus Sancti" (1831), an herbarium of plants from the Azores, the basis of Seubert's "Flora Azorica" (1844), and a special herbarium of plants from Morocco and the Zafarine Islands.

The Webb Herbarium does not have many holotypes of United States plants, but it does have a good selection of duplicates of early collectors, such as de la Pylaie, Darlington, Thomas Drummond (a large set), Nuttall, Riehl, Torrey, Tuckermann, A. Gray, Carey, Lindheimer, Wright, Douglas, Hartweg, Geyer, and others less well known. Among other valuable collections may be mentioned those of Turczaninov, Besser, and Schrank, from Siberia; Wight, Rottler, and Griffith, from India; Siebold, Oldham, and Buerger, from Japan; Karwinski, Jurgensen, Andrieux, and Linden, from Mexico; Schlim, Goudot, Linden, and Moritz, from Venezuela and Colombia; Jameson, from Ecuador (a large set of the early numbers); Philippi, Bridges, Bertero, Cuming, and Lechler, from Chile; and d'Urville, Drummond, von Mueller, Raoul, and Swainson, from Australia and New Zealand.

A special appendage of the Webb Herbarium is the Malaysian collection of Odoardo Beccari (1843-1920), which includes about 13,000 numbers from Borneo, Sumatra, and elsewhere. These were, of course, not a part of the original herbarium, but were purchased with Webb funds at the end of the nineteenth century. As mentioned above, the Beccari palms are in the Central Herbarium.

AFRICAN HERBARIA

There are two other large herbaria in Florence, the "Herbarium Libycum," containing the collections from Tripolitania, Cyrenaica, and Libya, and the "Herbarium Aethiopicum" or "Erbario Tropicale di Firenze," which has the plants from south of the Sahara, especially rich in those from Ethiopia, Eritrea, and Somaliland. In this century the staff members have specialized in the flora of northeast Africa, especially Emilio Chiovenda (1871–1940), well known for his "Flora Somala" (1929–1936), and R. E. G. Pichi-Sermolli, the curator in Florence for many years, and now associated with the Istituto Hanbury in Genoa. Under Pichi-Sermolli's direction, a series of papers on the flora of Ethiopia, Somaliland, and Socotra has been published under the title "Adumbratio Florae Athiopicae," in which 18 papers have been published and four more are in press. The ferns of Ethiopia are little represented in other herbaria, except for the early collections of Schimper, which are in many herbaria; Florence has one of the largest sets of this collector.

FERNS IN THE FLORENCE HERBARIUM

Due to the absence of a pteridologist during much of its existence, the ferns in the Florence Herbarium have received little study or attention. There are many interesting and valuable specimens nevertheless, including specimens from all the collectors mentioned above, among the most important being those of Raddi, Gaudichaud, Labillardière, and Hance. I spent two weeks in Florence in 1967 and could have profitably spent a much longer time in studying and photographing types. It is obvious that f r some reason very few pteridologists have ever visited Florence or borrowed material, for very few specimens are annotated or reidentified since the original determinations were made. This is to be regretted, for the material in Florence is of great importance.

Professor Fiori interested himself in ferns in his later years, and published his "Flora Italica Cryptogama, Pars V: Pteridophyta" during the war year 1943. It is a work of over 600 pages dealing solely with Italian pteridophytes, and is thus one of the most extensive fern floras. It is far from the best, even though it obviously represents a vast amount of work; however, this is not the place to present a critique of it. So far as it is based on specimens seen by Fiori, these are maintained in the Central Herbarium.

About 1940 Dr. R. E. G. Pichi-Sermolli became curator of the herbarium. His special interest in the ferns led to a rather complete reorganization of the genera, mostly following Christensen's concepts. This reorganization included the ferns in the Webb Herbarium as well as in the Central Herbarium. As a result, it is easy now to find material, having Christensen's "Index Filicum" in hand, for the arrangement is alphabetical, which seems to me in the end to be the simplest, both for filing and finding material. After all, an herbarium is not intended to express relationships or changing opinions on phylogeny. The ferns are kept in bundles in very high, glass-fronted cabinets, and so one must use ladders constantly; however, those in use today are solid and sturdy, and one is unlikely to fall from them.

In November, 1966, Florence suffered a major disaster, an extensive flooding from the Arno River, which overflowed its banks and placed the downtown part of Florence under as much as 18 feet of water. When I was there some eight months later, the destructive effect was still evident, although the major streets had been repaired. The damage was great everywhere, but doubtless the major loss was the National Library, which was near the river. The second floor collapsed, sending most of the books and the catalogue into the flood. Many rare and probably some unique books and manuscripts were lost. The herbarium, situated almost a mile from the river and on somewhat higher ground, did not suffer; it could never have been under water in any case, since it is on the high second and third floors of the building. However, the staff was called in for the emergency, and everyone worked at removing the folio books from the lower shelves in the library. This turned out to be an extremely wise precaution because the flood just reached the building and water did reach the first shelves of the library, which is on the ground floor. There was not time enough to remove the reprints, which did get soaked. Again the staff got together to air and dry them, and most were saved, although with oil and water damage. The sets of duplicate plant specimens in the cellars were ruined, as were most of the reserve stocks of Webbia and other journals. A good deal of the property damage and loss of life could probably have been averted if the provost, the top government official, had notified the police and the citizens in advance of the flood danger; it has been stated that this was not done because of the possibly greater damage that might have resulted from a general panic. My information concerning the flood comes from the American botanist Dr. Harold St. John, who was in Florence at the time studying the world's greatest collection of *Pandanus*, assembled by Count Ugolino Martelli.

Much of the information concerning the history of the herbaria in Florence has been taken from the book "Les Collections Botaniques du Musée Royal de Physique et d'Histoire Naturelle de Florence," by Philippe Parlatore (pp. 1–163, pl. 1–17. 1874), a copy of which was kindly lent to me by Professor Guido Moggi, the present curator of the herbarium in Florence. I am indebted to Professor Eleonora Francini-Corti, the Director of the Istituto Botanico, and to Professor Moggi for permission to study in the herbarium in 1967.

(*To be continued*)

Responses of Some Indian Species of Marsilea to Different Temperature Treatments

BRIJ GOPAL

The various species of the aquatic fern genus *Marsilea* grow in India throughout the year, braving the vagaries of climate and thus indicating their wide tolerance to different factors of climate, of which temperature is one of the most important. Different species seem to have different temperature tolerance ranges. *Marsilea quadrifolia* grows in Kashmir (Gupta, 1962) where the winter temperature goes far below freezing, whereas *M. aegyptiaca* occurs even on bare rocks and survives summer temperatures exceeding 50°C in Jodhpur (Gopal, 1968). It is true that water plants are at an advantage inasmuch as the fluctuations in water temperature are not so wide, but this does not altogether apply to amphibious plants like *Marsilea*, which pass a part of their life under terrestrial conditions during the dry season. These considerations led to some experiments on five Indian species of *Marsilea: M. aegyptiaca, M. maheshwarii, M. minuta, M. quadrifolia*, and *M. rajasthanensis*. Their responses to different temperature treatments are reported below.

In all the experiments five-internode pieces of rhizome taken from clonal cultures were transplanted to earthen pots. After three days, when the plants had become well established, they were subjected to the various experimental treatments.

In the first set of experiments, the potted plants were kept at three different temperatures: (i) at a constant 15°C in a phytotron chamber, (ii) in an open garden where the temperature fluctuated between 25°C at night and 40°C during the day, and (iii) in a phytotron chamber at 15°C during the night and in the open at 38–40°C during the day. In the first two treatments normal growth occurred, but the total dry matter accumulation was more than twice as much at the higher daytime temperature than at continuous 15°C. There was almost no growth in the third treatment where the diurnal temperature was about 25°C hotter than the nocturnal. The rhizomes grew a little, but no laminae developed in any of the leaves that were produced. In some cases, however, young primordia of four leaflets could be observed under a lens.

In another experiment the plants were subjected to a period of subfreezing temperatures (− 13 ± 2°C) for varying periods of 30 minutes to 24 hours. A control set of plants without cold treatment was also maintained. After a single exposure to this low temperature, the plants were returned to the open in a garden and watered daily. No appreciable decline in growth was noted in any of the five species after an exposure of up to two hours. At a four hour exposure all the species except *M. quadrifolia* showed more than a 50% mortality, and plants of *M. aegyptiaca* had as high as a 90% mortality. At an eight hour exposure mortality increased, growth was considerably reduced in the surviving plants, and a 50% mortality was noted in *M. quadrifolia.* Only *M. quadrifolia* survived a twelve hour exposure, but even this species could not withstand 24 hours of exposure.

Another set of plants of the five species was subjected to a daily exposure of one to twelve hours of subfreezing temperatures for a period of two weeks. Only 50% of *M. quadrifolia* plants survived after two weeks of a one hour daily exposure. No other species could withstand any of these temperature cycles.

These experiments clearly indicate how well the different Indian species of *Marsilea* tolerate various temperatures. It is quite clear that the different species cannot withstand subfreezing or widely fluctuating temperatures. The five *Marsilea* species under observation do exhibit an adaptation to a wide range of temperatures from 15°C to 40°C. The survival of *M. quadrifolia,* a species with a more northern natural range, under subfreezing temperatures can easily be explained by the thermal properties of water and ice. When water freezes, ice forms on the surface that acts as an insulating cover and keeps the water beneath at a much higher temperature than the atmosphere above.

Another important observation is the failure of the lamina to develop at widely fluctuating temperatures, such as 15°C at night and 38–40°C during the day. Milthorpe (1956) has demonstrated that in the cucumber, "the leaves initiated at low temperature and transferred to a higher temperature do not attain such large size as leaves held all the time at higher temperature." Similarly, Schwabe (1963) noted in *Chrysanthemum* "that apical growth is less affected by temperature than subsequent leaf expansion has been noted by several workers; though no definite explanation is known one might be tempted to speculate on the differences in this respect between the processes of mitosis and cell expansion perhaps controlled by hormone levels. In *Chrysanthemum* . . . leaf blades are suppressed not merely because cell expansion does not occur but also because division is reduced." A similar situation also appears to occur in the species of *Marsilea*. The usual development of the petiole but the failure of the lamina to expand demonstrates that the sudden change from a low to high temperature does not affect the apical growth of the petiole, but only the cell division and expansion in the lamina. These observations, supplemented by further work, will be discussed elsewhere.

I wish to express my grateful thanks to Prof. R. Misra and Dr. K. C. Misra for their helpful suggestions.

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External Factors Inducing Germination of Fern Spores[1]

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The dependence of spore germination on light in most species of ferns was established by nineteenth century biologists including Borodin, Schmidt, Kny, and Beck (see the excellent review of Sussman, 1965). However, there are conflicting reports on the ability of spores of certain species to germinate in the dark. For example, Borodin (1865), Schulz (1902), and Life (1907) were unable to demonstrate the germination of spores of *Anemia phyllitidis* in the dark, although Schelting (1875) claimed that it occurs. The light requirement for germination in various species has been found to be complex. Ability of spores to undergo dark germination may vary, for example, with age (Laage, 1907), with pretreatment at various temperatures (Heald, 1898; Schulz, 1902), or with exposure to various plant hormones. Reliable action spectra for light-induced promotion and inhibition of germination in species of *Dryopteris* and *Osmunda* (Bünning and Mohr, 1955; Mohr, 1956; Mohr et al., 1964) show maxima at the absorption maxima of phytochrome.

Gibberellic acid stimulation of dark germination, reported by Schraudolf (1962), was the first true case of a specific replacement of a light requirement in spore germination. Kato (1955) reported a gibberellin stimulation of germination in *Dryopteris erythrosora* and *Cyathea* sp., but this consisted merely of gibberellin promotion of rhizoid and protonemal growth in light. More recently Näf (1966) has confirmed Schraudolf's observations and reported that dark germination is stimulated in *Lygodium japonicum* by gibberellic acid and in *Anemia phyllitidis* by an antheridogen-B preparation as well as by gibberellin. Näf also claimed a weak stimulation of germination of *L. japonicum* by antheridogen-B and by the medium upon which *L. japonicum* had been growing. However, these latter results seem to be based on counts of only

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60 spores. Thus, the response represents the germination of very few spores. Moreover, his use of crude culture filtrates rather than purified antheridogen-B raises the possibility that the observations, if valid, resulted not from response to antheridogens, but to other factors present in the culture medium.

The pH optima for germination have been reported for a limited number of ferns and fern allies (see Sussman, 1965). In general they lie on the acidic side of neutrality, from pH 5.0 to 7.0. Mohr (1956) reported failure of germination at either pH 3.0 or 10.0, and maximum germination between 5.0 and 5.5 for *Dryopteris filix-mas.* We have shown a striking pH dependence of gibberellic acid stimulated dark germination in *Anemia phyllitidis* (Weinberg and Voeller, 1969). Maximum dark germination in this species occurs at pH values of 4.5 and lower. Within a three week time period, virtually no dark germination can be induced at values above 6.0. In striking contrast, illuminated spores of *A. phyllitidis* germinate nearly equally well from pH 3.5 to 7.0. These results demonstrate that it is imperative to conduct experiments with germinating spores in a properly buffered medium if responses to light and darkness are to be compared.

In the present study we report results derived from testing the light dependence of spore germination in species from eight families of ferns and the ability of gibberellin to replace the light requirement when it exists. The effects of various external conditions on germination of one fern, *Anemia phyllitidis*, a commonly used experimental test object, are considered in fuller detail.

MATERIALS AND METHODS

The source of spores used in these studies is indicated in *Table I.* Spore-producing plants of *Anemia phyllitidis* (L.) Swartz were grown in the greenhouses of the Rockefeller University. Spores of all species were collected, sieved, and stored at 4° C until use (Voeller, 1964a).

Potassium gibberellate (Calbiochem) was twice recrystallized in the acid form (dec. 210–211°). Gibberellic acid (GA_3) to be used in media was first dissolved in a few drops of warm $NaHCO_3$

(50 mg/ml), brought to appropriate volume with distilled water, and filter-sterilized through Millipore Swinnex filter units. Other gibberellins used were the generous gift of Dr. D. Broadbent of Imperial Chemical Industries, Ltd. Each gibberellin was sufficiently pure and free of contaminants to appear as a single spot of appropriate R_f in the following chromatographic test system. Aliquots of the gibberellins were spotted on silica gel sheets (Eastman Chromagram sheet 6061, without fluorescent indicator) and developed with di-isopropyl ether-acetic acid (95:5) after the method of MacMillan and Suter (1963). R_f's were determined by locating fluorescent spots which become visible after spraying the chromatograms with 5% sulfuric acid in ethanol and heating for several minutes at 80–85°C.

Antheridogen-B from gametophytes of *Anemia phyllitidis* was prepared in a manner similar to that for obtaining antheridogen-A (Pringle et al., 1960). However, cultures of *A. phyllitidis* were grown for 8–12 weeks on 50 ml of agar-gelled Moore's medium in 125 or 250-ml Erlenmeyer flasks. The agar was freed of gametophytes and extracted three times at −10° C for 24–48 hours with equal volumes of methanol. The methanol extracts were pooled and evaporated *in vacuo* at temperatures below 45° C. The remaining aqueous concentrate was combined with 0.05M phosphate-citrate buffers and treated with ethyl acetate in a manner similar to that used in antheridogen-A preparation (Pringle et al., 1960).

Spores were surface-sterilized in 100 mg (dry weight) batches in 15% Chlorox for 10 minutes (Voeller, 1964a). They were then centrifuged and resuspended in 10-ml sterile water aliquots for a series of three washes and finally resuspended in 10 ml of sterile water, giving a spore concentration of approximately 10 mg/ml. Inoculations were made from these suspensions with sterile serological or Pasteur pipettes.

Moore's (1903) liquid culture medium supplemented with a trace element solution (Gorham, 1945) was used for culturing gametophytes. The medium was buffered at pH 4.5 with 2-(N-morpholino) ethanesulfonic acid (MES) at a concentration of 0.05M (Voeller and Weinberg, 1969; Weinberg and Voeller, 1969). Culture vessels were 15 × 100 mm test tubes each containing one ml of medium. All cultures were maintained at 21 ± 2° C. Those grown in light received approximately 7500 lux from banks of twelve 8-foot GE Cool White fluorescent bulbs and six 60-watt incandescent bulbs.

The percentage of germination was determined by microscopically observing and counting a fixed number of spores from each of several culture vessels. If the spore wall was dehisced or

TABLE I. GERMINATION RESPONSE TO LIGHT, DARKNESS AND GIBBERELLIC ACID (GA_3, 10^{-4} G/ML) IN EIGHT FAMILIES OF FERNS[1]

Species	*Light*	*Dark*	*GA_3*
CYATHEACEAE			
Alsophila australis R. Brown	+++	−	−
PTERIDACEAE			
Adiantum pedatum L.	+++	−	−
Cibotium barometz (L.) J. Smith	++	−	−
Pellaea hastata (Thunb.) Prantl[2]	+++	−	−
P. viridis (Forsk.) Prantl	+++	−	−
Pteris cretica L.	+	−	−
P. ensiformis Burm.[2]	+	−	−
P. longifolia L.	+++	−	−
P. tremula R. Brown[2]	+	−	−
Pteridium aquilinum (L.) Kuhn	+++	+++	+++
DAVALLIACEAE			
Scyphularia pentaphylla (Blume) Fée	+	−	−
Nephrolepis cordifolia (L.) Presl[2]	++	−	−
ASPIDIACEAE			
Athyrium filix-femina (L.) Roth	+++	−	−
Cyrtomium falcatum (L.) Presl	+++	−	−
Matteuccia orientalis (Hooker) Trev.	+	−	−
Polystichum munitum (Kaulf.) Presl	+++	+	+
Tectaria sp.	+++	−	−
Woodsia obtusa (Spreng.) Torrey	+++	−	−
Onoclea sensibilis L.	+++	−	−
BLECHNACEAE			
Blechnum occidentale L.	+	−	−
POLYPODIACEAE			
Phlebodium aureum (L.) J. Smith	+++	−	−
Polypodium feei (Bory) Mett.	++	+	+

Species	*Light*	*Dark*	*GA$_3$*
Osmundaceae			
Todea barbara (L.) Moore[3]	+++	–	–
Schizaeaceae			
Anemia collina Raddi[4]	+++	–	+
A. hirsuta (L.) Swartz	++	–	+
A. phyllitidis (L.) Swartz	+++	–	+++
A. rotundifolia Schrad.[4]	+	–	+
A. tomentosa (Sav.) Swartz	+++	–	+
Lygodium flexuosum (L.) Swartz[5]	+	–	?
L. japonicum (Thunb.) Swartz	+++	–	++
L. palmatum (Bernh.) Swartz	+	–	+
L. scandens (L.) Swartz	+++	–	+
Mohria caffrorum (L.) Desv.[6]	++	–	++

[1] Germination: – = less than 2%, + = 2–10%, ++ = 10–20%, +++ = more than 20%. Counts made of 200 spores. Unless otherwise noted, spores collected by the authors.

[2] Spores purchased from Albert Schenkel, Hamburg, Germany; identity not checked.

[3] The gift of H. P. Van Der Schijff, Pretoria, South Africa.

[4] The gift of G. Pabst, Rio de Janeiro, Brazil.

[5] The gift of N. D. Balakrshnan, India.

[6] The gift of H. B. Rycroft, Kirstenbosch, South Africa.

open and the spore cell appeared to be intact, the spore was considered to be germinated.

Light Requirement of Various Species

The results presented in *Table I* indicate that only three of the many species tested germinate in darkness in excess of 2% under culture conditions in which each species germinates if illuminated. Interestingly, the three dark germinating species, *Pteridium aquilinum*, *Polystichum munitum* and *Polypodium feei* are in different families. With the exception of species of the Schizaeaceae, no species could be shown to germinate in darkness as a consequence of exposure to gibberellic acid. Two species showing germination in the presence of gibberellic acid spontaneously germinated to the same extent in dark controls lacking gibberellic acid.

In striking contrast to the response of the seven other families, spores of all but one tested member of three genera in the Schizaeaceae germinated when GA_3 was used to replace light as the agent promoting germination. GA_3–replacement of the light requirement was particularly marked in *Anemia phyllitidis, Lygodium japonicum,* and *Mohria caffrorum.*

The response of the various schizaeaceous ferns in our experiments differed in the length of the lag period before dark germination could first be seen. In *A. phyllitidis, A. tomentosa, A. hirsuta,* and *M. caffrorum,* the response could be seen within one week of inoculation, whereas the other spores which responded to GA_3 did not germinate until the second week. All light-treated spores germinated within the first week. Treatment with GA_3 at 10^{-4} g/ml did not result in as many spores germinating as did continuous light, except for *A. phyllitidis* and *M. caffrorum.*

VARIATION IN GERMINATION WITH SPORE BATCH

Spores of *A. phyllitidis* were harvested in our greenhouse every few days and spores of a harvest period of two weeks to one month were pooled. These batches showed great variation in germination level under uniform conditions. The best samples exhibited 60–70% germination; others, however, showed only 5% germination. Similar variation was also noted by Mohr et al. (1964) in two species of *Osmunda.*

In addition to the variation noted above, samples differed in the time necessary for germination to commence after a light or gibberellin stimulus was provided. Moreover, the gibberellin concentration or the time in light required to achieve maximum germination varied somewhat for different spore batches. With one spore sample, for example, a GA_3 concentration of more than 10^{-5} g/ml was required to saturate the system, whereas for another spore sample 10^{-6} g/ml sufficed for saturation. Although these two cases represent extremes, they illustrate well the variation among different spore batches.

No exact seasonal correlation could be made with the germination capacity of the spores. However, periods of vigorous spore formation resulted in production of spores which gave higher germination levels.

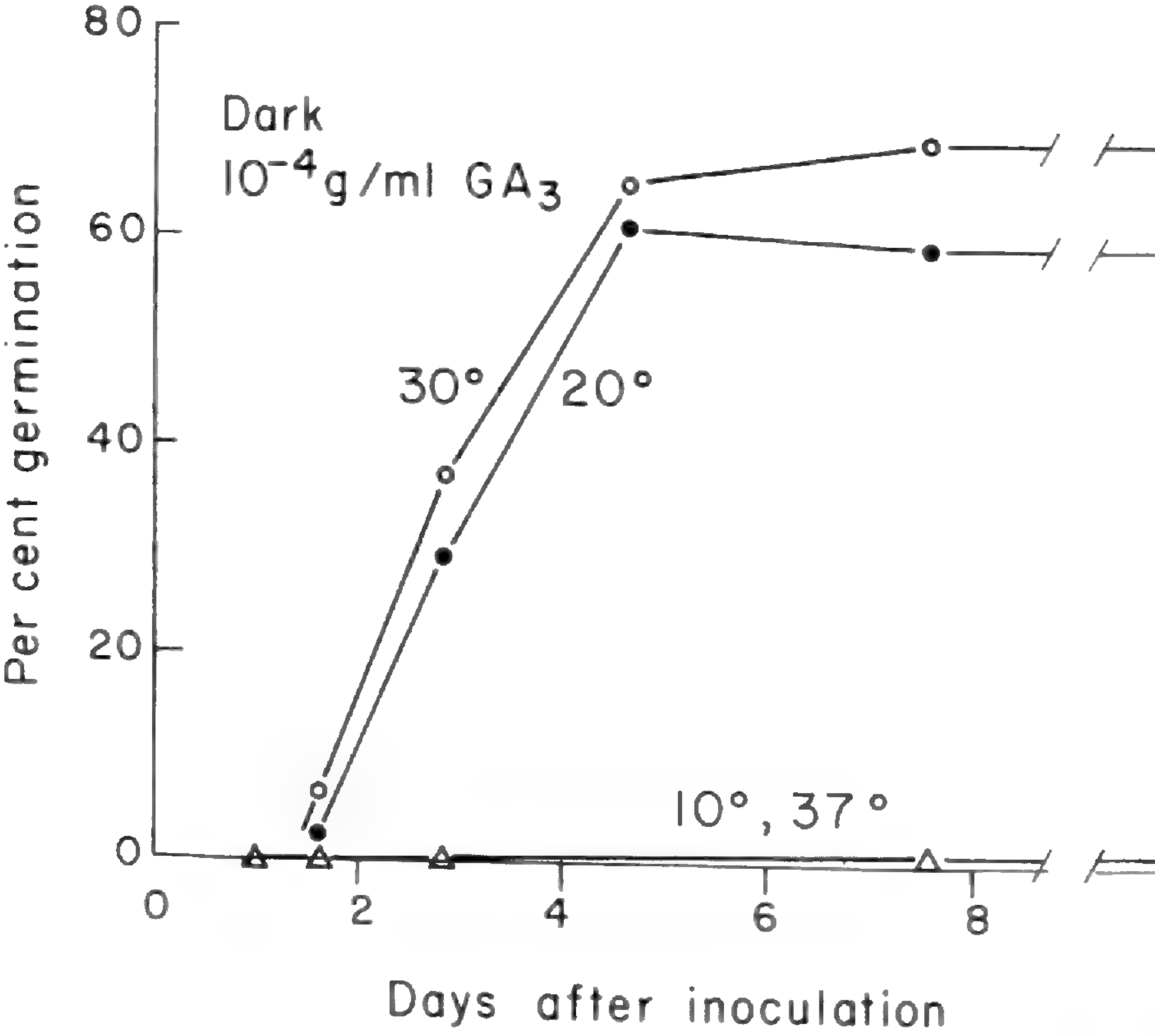
EFFECT OF TEMPERATURE

Although there have been reports of *A. phyllitidis* spores which are able to germinate in the dark at 30°C (Schelting, 1875), such dark germination was absent in Life's (1907) studies and was very rare in our experiments. Spores were inoculated into MES-Moore's medium at pH 4.5 and left in the dark at 10°, 20°, 30° and 37° C. Final counts made three weeks after inoculation showed less than 0.5% germination at any of these temperatures. Under parallel conditions using the same spore inoculum, GA_3-treated spores gave extensive germination at 20° and 30° C, but no germination at 10° and 37° C (*Fig. 1*).

Extensive light-induced germination was obtained with spores of *A. phyllitidis* which had not been refrigerated. Thus, there is no stratification requirement for germination in this species, a result not unexpected in view of the fern's tropical habitat.

EFFECTS OF LIGHT AND GIBBERELLIC ACID

As already seen, most of the species used in this study show a light requirement for germination under our culture conditions (*Table I*). The effect of light upon germination was more fully studied in *A. phyllitidis* by exposing freshly inoculated cultures to light for various times and then allowing germination to proceed in the dark. As seen in *Figure 2,* 6 hours in the light resulted in but a slight increase in germination over dark controls. Half saturation (50% of total spore germination) was reached at about 17 hours in the light, and the system became fully saturated with light exposures between 24 and 48 hours. The gibberellin concentration giving germination half that of the saturation value was between 2 and 5×10^{-7} g/ml, whereas the concentration giving saturation was about 10^{-4} g/ml. The histograms illustrate the final germination levels. We have shown elsewhere that the rate of germination, as well as the final germination level, varies



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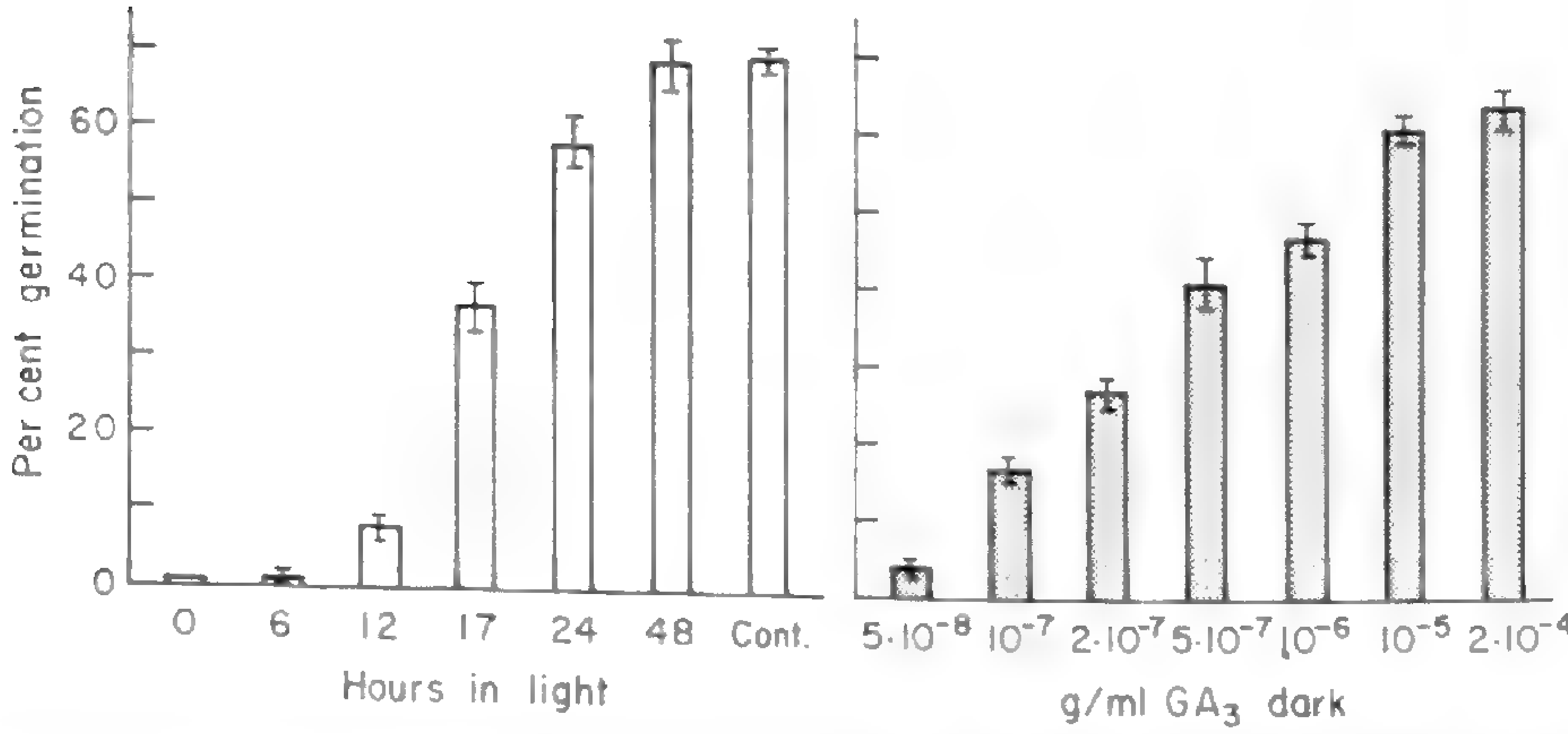

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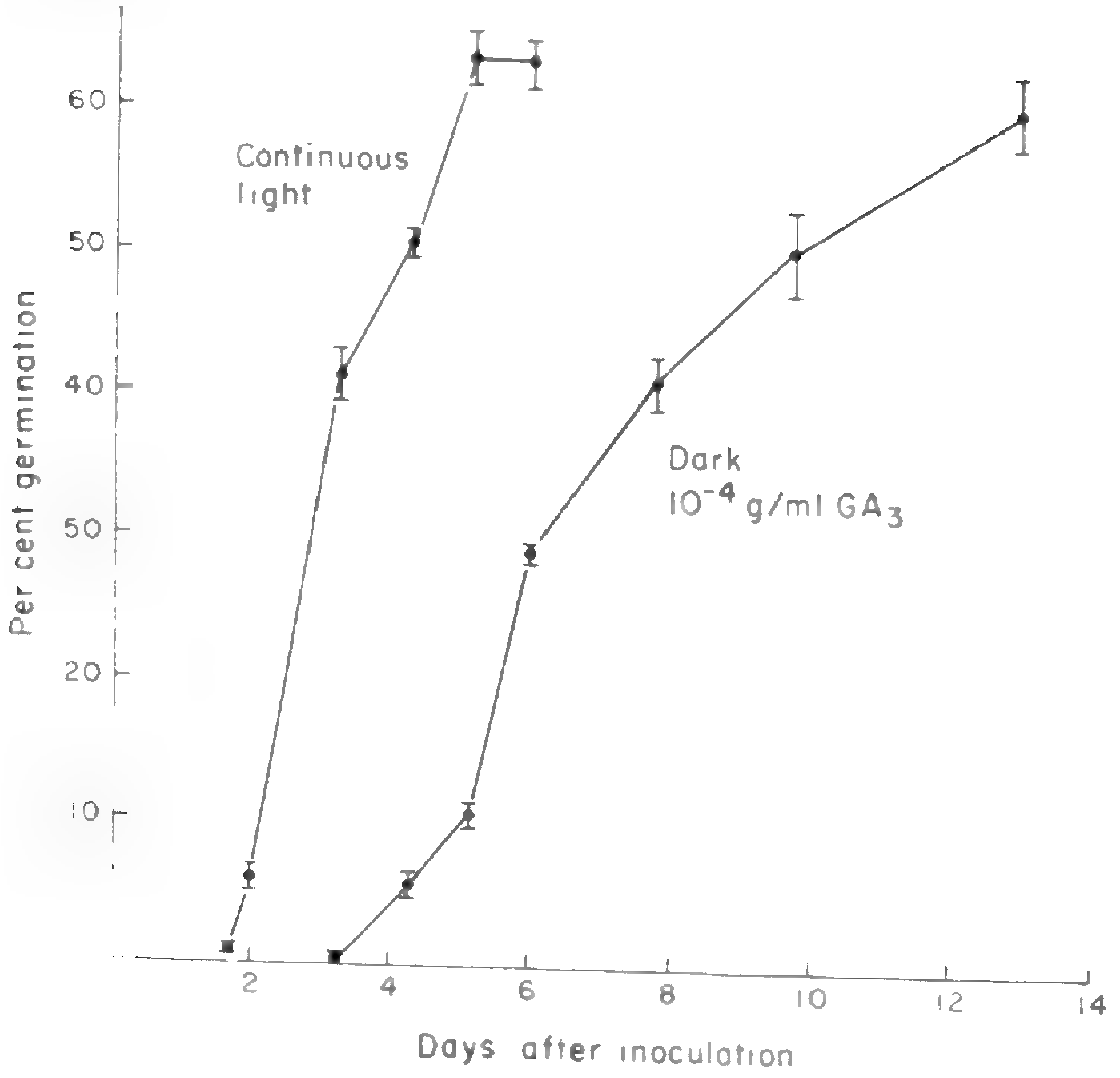
FIG. 1. GERMINATION OF A. PHYLLITIDIS SPORES AT VARIOUS TEMPERATURES IN THE DARK. EXPERIMENTAL POINTS REPRESENT THE MEANS OF TWO REPLICATES; 200 SPORES PER REPLICATE. FIG. 2. DOSE-RESPONSE CURVES FOR GERMINATION OF A. PHYLLITIDIS SPORES EXPOSED FOR VARIOUS TIMES TO LIGHT OR TREATED WITH VARIOUS CONCENTRATIONS OF GA$_3$ IN THE DARK. EACH VALUE IS THE MEAN (± THE STANDARD ERROR) OF THE FINAL PER CENT GERMINATION OBTAINED IN FOUR REPLICATES OF 200 SPORES EACH.

with the length of the light treatment (Weinberg and Voeller, 1969). Unpublished results of E. S. Weinberg and M. J. Schneider indicate that the light effect on germination in *A. phyllitidis* is phytochrome moderated.

Increasing the concentration of GA_3, just as increasing the time in light, causes an earlier appearance of germination and a somewhat more rapid rate of germination. However, gibberellin-treated samples usually show a later appearance of germination than do light-treated spores. When saturating conditions of light and saturating GA_3 concentrations are used, dark germination usually begins one day after the onset of light germination (*Fig. 3*). The time necessary to achieve the maximum level of germination also differs; continuous light cultures generally achieve complete germination within 5 or 6 days, whereas GA_3-induced dark germination is not usually complete until about 12 to 14 days. It must be noted, however, that on occasion this distinction was much less striking and the curves for light and dark GA_3-induced germination were nearly alike.

EFFECTS OF DIFFERENT GIBBERELLINS ON SPORE GERMINATION

The observations of Voeller (1964a, 1964b) and Schraudolf (1964, 1966) on the relative activity of various gibberellins in antheridium induction prompted testing these hormones on spores of *A. phyllitidis* for activity in promoting dark germination. The dose-response curves of the five most active gibberellins are plotted in *Figure 4*. Saturating levels were possibly not reached for GA_1 and GA_3 in this experiment. However, saturating levels were reached at 10^{-6} g/ml for GA's 9, 7 and 4. A higher percentage of spores responds to saturating levels of either GA_4 or GA_7 than to saturating levels of GA_9. This result was obtained in two independent experiments. Two additional gibberellins were tested, GA_5 and GA_8. The endpoint of activity for GA_5 was between 10^{-5} and 10^{-6} g/ml. Activity was obtained with GA_8 at a concentration as low as 2×10^{-7} g/ml. The following relative activity of gibberellins was determined by measuring endpoint: $GA_4 = GA_7 > GA_9 > GA_1 \geqslant GA_3 > GA_8 > GA_5$. Germination in response



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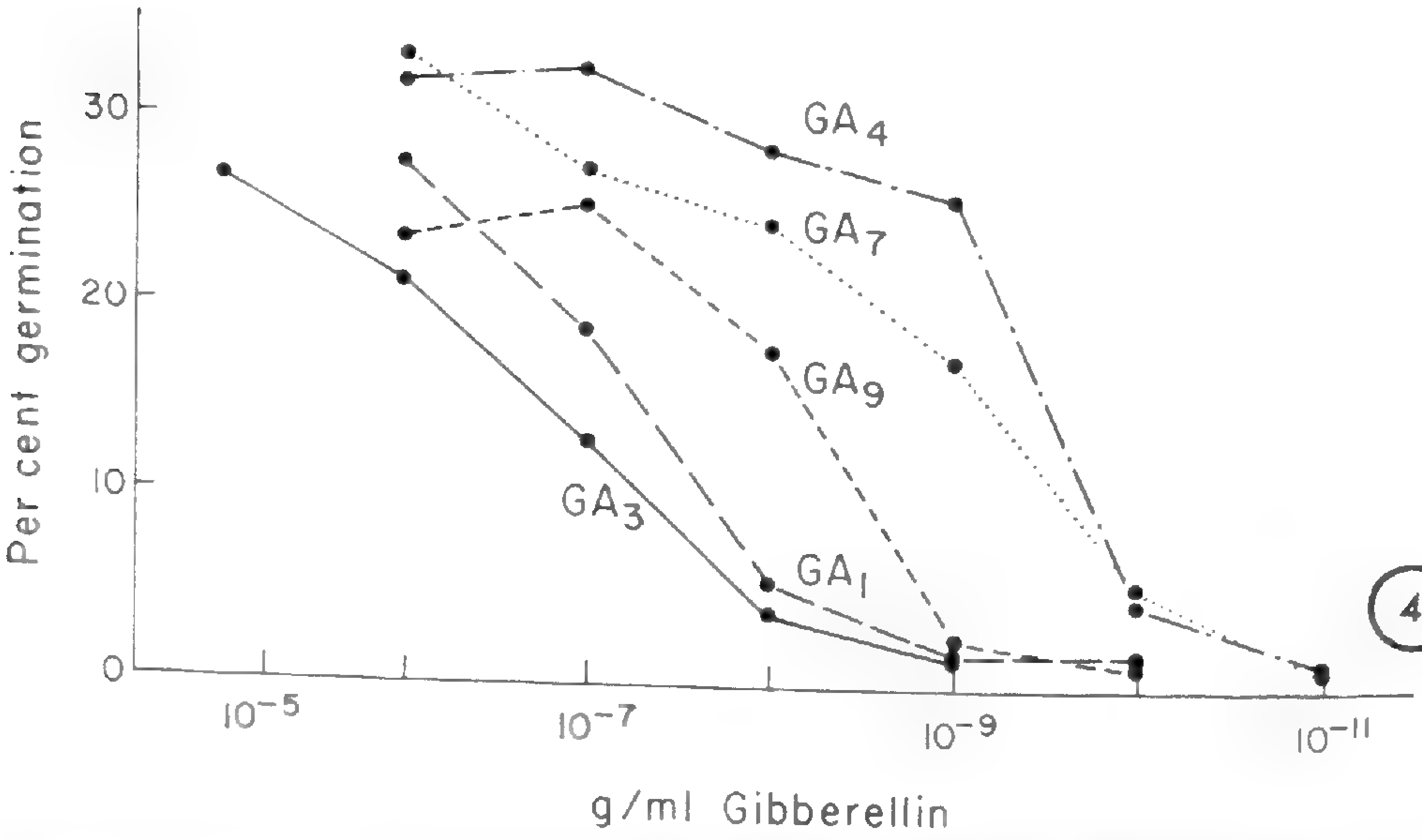

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FIG. 3. DIFFERENCE IN RATE AND TIME OF INITIAL GERMINATION IN A. PHYLLITIDIS SPORES TREATED WITH SATURATING LIGHT AND GIBBERELLIN. MEANS (± STANDARD ERROR) OF FOUR REPLICATES OF 200 SPORES EACH. FIG. 4. DOSE-RESPONSE CURVES FOR INDUCTION OF A. PHYLLITIDIS SPORE GERMINATION BY FIVE GIBBERELLINS. EACH EXPERIMENTAL POINT IS THE MEAN OF THE PER CENT GERMINATION 14 DAYS AFTER INOCULATION IN EACH OF TWO REPLICATES OF 300 SPORES EACH.

to GA_4 or GA_7 is sensitive to concentrations as low as 10^{-10} g/ml, or in terms of molarity, 3×10^{-11}M, which is close to the level of sensitivity of the barley endosperm assay (Jones and Varner, 1967; Coombe et al., 1967).

Very similar relative activities were obtained for gibberellin-induced antheridium formation (Voeller, 1964a, 1964b; Schraudolf, 1964). However, the germination response is at least twice as rapid as the antheridium response at the lower concentration ranges and is more sensitive to low concentrations of every gibberellin tested. Spores are sensitive to each applied gibberellin, yet vary quite dramatically in their dose-response curves. Thus, this germination assay might be added to the list of valuable gibberellin bioassays. Easily separable in this assay are activities of gibberellins GA_5, GA_8, GA_1–GA_3, GA_9 and GA_4–GA_7. In combination with the barley endosperm assay (Jones and Varner, 1967), which is sensitive to GA_1, GA_3, GA_4 and GA_7 approximately to the same extent, and the dwarf bean assay (Brian et al., 1964), which easily separates activity of GA_1 from GA_3 and GA_4 from GA_7, the *Anemia phyllitidis* dark germination assay may be particularly useful.

TABLE II. DARK INDUCTION OF GERMINATION BY ANTHERIDOGEN–B[1]

Species	*Light*	*Dark*	*GA_3*	*AB*[2]
Anemia collina	+++	−	+	+
A. hirsuta	++	−	+	+
A. phyllitidis	+++	−	+++	+++
A. rotundifolia	+	−	+	+
A. tomentosa	+++	−	+	+
Lygodium flexuosum	+	−	?	−
L. japonicum	+++	−	++	−
L. palmatum	+	−	+	− − −
L. scandens	+++	−	+	−
Mohria caffrorum	++	−	++	+

[1] Experimental results scored as follows: − = less than 2% germination, + = 2–10% germination, ++ = 10–20% germination, +++ = more than 20% germination. Counts made of 200 spores.

[2] AB = antheridogen–B, active in antheridium formation in *A. phyllitidis* to a dilution of 1:5000.

EFFECTS OF ANTHERIDOGEN-B

Preparations of antheridogen-B were found by Näf (1966) to induce dark germination in *A. phyllitidis.* He tested one other species, *Lygodium japonicum,* and reported a very weak response to antheridogen-B. In order to determine if the spores of various species had a similar response to antheridogen-B as to GA_3, a preparation of antheridogen-B at a dilution of 1:40 was added to suspensions of spores of various species. The results are given in *Table II*. All representatives of the genus *Anemia* germinated in response to antheridogen-B. Spores of *Mohria caffrorum* also responded. However, all *Lygodium* spores tested were, in our hands, insensitive to even the highest concentrations of antheridogen-B used. Three non-schizaeaceous species, *Pellaea viridis, P. hastata,* and *Athyrium filix-femina,* also failed to germinate in response to antheridogen-B. It thus appears possible that the action of antheridogen-B is more specific than that of GA_3; entire genera within the Schizaeaceae appear to respond or not. At the concentration employed (1:40) the hormone was as effective as 10^{-4} g/ml GA_3 in producing high germination levels in only three ferns tested: *A. phyllitidis, A. tomentosa,* and *M. caffrorum.* In *A. tomentosa* the antheridogen-B response was even more pronounced than the response to GA_3.

The hormone preparation was active in promoting dark germination in spores of *A. phyllitidis* when diluted 1:10,000,000. Thus, this preparation was more than 100 times as active as that used by Näf (1966) in his studies on germination. Despite this difference in biological activity, his experiments show a slight antheridogen-B stimulation of dark-germination of spores of *L. japonicum,* in contrast to the findings reported here. Possible causes of the difference in our results are the use of genetically different stocks, rather small sample size in Näf's experiments (only 60 spores were counted), and the relative impurity of Näf's antheridogen (unpurified *Anemia* medium was used). However, spores of *Lygodium* have proved to germinate with considerable variability and it would be unjustified to draw a clear conclusion at this time concerning their response to antheridogen-B.

EFFECTS OF OTHER PLANT HORMONES, THIOUREA AND NITRATE

The synthetic auxin, naphthalene acetic acid, was without effect at concentrations from 5×10^{-9} to 5×10^{-5} g/ml. The three purine-cytokinins, kinetin, benzyladenine, and zeatin, also had no effect on dark-germination at any of several tested concentrations. Kinetin has been shown to promote the dark germination of lettuce seeds (Miller, 1956, Skinner et al., 1956; Ikuma and Thimann, 1963; Leff, 1964), which are also strongly responsive to gibberellin. The effect of kinetin is an enlargement of the cotyledons rather than the usual elongation of the epicotyl, which is characteristic of gibberellin or red light-induced germination (Scheibe and Lang, 1965).

It has been reported that nitrate (Lehman, 1909; Evenari, 1965) and thiourea (Thompson and Kosar, 1938, 1939; Evenari, 1965) possess germination stimulating activity in seeds. However, 0.1M KNO_3, 0.1M $NaNO_3$ and 5×10^{-3}M thiourea were inactive in promoting dark germination in spores of *Anemia phyllitidis*.

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Shorter Notes

POLYPODIUM VULGARE VAR. VIRGINIANUM ON CAPE COD SANDS.—Recently F. R. Fosberg (Amer. Fern J. **58:** 153–154. 1968) reported the European *Polypodium vulgare* var. *vulgare* from western Long Island, New York, where a colony of the plants was growing on sand in a patch of hardwood forest. Noting that the American *P. vulgare* var. *virginianum* does not normally occur on sand[1] and that *P. vulgare* var. *vulgare* had not previously been reported in eastern United States, Fosberg suggested that the best approach towards determining whether the European variety is indigenous on Long Island might be to search for and examine plants from other coastal plain and morainal stations of *P. vulgare.*

Polypodium vulgare is rare and highly localized on Cape Cod, Barnstable County, Massachusetts. In June of this year I re-examined specimens from two of the larger colonies of the fern and found them to be *P. vulgare* var. *virginianum* as characterized by the presence of glandular paraphyses in the sori. At both stations where the ferns were studied, the "Provincelands" area within the Cape Cod National Seashore and Lowell Holly Reservation in the town of Mashpee, the ferns were growing in mature and highly-developed forest under a canopy dominated by beech, *Fagus grandifolia,* and rooted in a sandy substratum which contained abundant organic material. Common herbaceous associates at both sites included *Maianthemum canadense, Trientalis borealis,* and *Aralia nudicaulis.* The sands of the "Provincelands" are of marine origin and have been available for colonization by land plants for less than 6000 years; those of the Lowell Holly Reservation are primarily glacial in origin and have been available for colonization since the last glaciation. Nonetheless, the possibility that man may have been responsible for the presence of even this American plant on these sites cannot be excluded: the "Province-

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[1] Dr. Wherry has written, on the other hand, that "*Polypodium virginianum* is well known to Philadelphia collectors to grow on wooded sandy slopes scattered throughout the Coastal Plain of southern New Jersey, except in the more acid pine-barren areas, and is documented by local herbarium specimens."—ed.

lands" was set aside as a reserve supposedly by the Pilgrims and maintained as a state park before its inclusion in the National Seashore. Several pine species have been planted in adjacent areas, and it is not impossible that *P. vulgare* var. *virginianum* was inadvertently introduced with them as it apparently has been on nearby Nantucket Island, according to Eugene P. Bicknell (Bull. Torrey Bot. Club **44:** 369. 1917). Regardless of its origin, *P. vulgare* var. *virginianum* is flourishing at both these sites, the colony at the Lowell Reservation extending for hundreds of square feet.—C. JOHN BURK, *Smith College, Northampton, Mass.* 01060.

Notes and News

Dr. Edgar T. Wherry reports that his "Southern Fern Guide" will soon be out of print and that the publisher does not plan to reprint it. Persons interested in the ferns of the southeastern United States would do well to purchase a copy of the "Guide" before it becomes a collector's item.

BOOKS WANTED—If you wish to sell the following books, please write to me stating the price: "Book of Choice Ferns," vols. 1–3, by George Schneider, and "Ferns, British and Exotic," vols. 1–8, by E. J. Lowe.—Mrs. W. F. Radcliffe, 636 S.E. 5th Place, Hialeah, Fla. 33010.

Recent Fern Literature

INTERSPECIFIC RELATIONSHIPS IN THE POLYPODIUM PECTINATUM–PLUMULA COMPLEX, by A. Murray Evans. Ann. Missouri Bot. Gard. **55:** 193–293. 1969.—Contrary to its title, this is essentially a taxonomic revision rather than a study of relationships, which are discussed only rather briefly, and as such it is an important contribution to our knowledge of a widespread and common group of American Polypodiums. The number of species and their definition has been uncertain, which has made naming these rather commonly collected plants difficult. Dr. Evans recognizes 26 species, a good many of which have generally been called merely *P. pectinatum* L. or *P. plumula* Humb. and Bonpl.

Many of the species bear a superficial resemblance to plants of *Grammitis* sect. *Cryptosorus* (the genus "*Ctenopteris*" of Copeland), from which they differ in basic characters of spores, pubescence, scales, and gametophytes. The treatment includes discussions of the morphology, ecology, life cycles, and evolution, and there are photographs, drawings, and maps of the distribution. This is altogether a very satisfactory monograph.—C. V. M.

FLORA DER SCHWEIZ UND ANGRENZENDER GEBIETE, vol. 1, by H. E. Hess, E. Landolt, and R. Hirzel, Published by Birkhäuser Verlag, Basel, Switzerland, 1967.—This newest European flora presents both a more conservative and more usable treatment of the European ferns than the "Flora Europaea," although of course not all the ferns of Europe are treated. Still, the Swiss flora is quite rich in ferns, and so most European species are covered. All the species are keyed and described fully enough, and almost all are illustrated by line drawings. The most useful feature is perhaps the comments, in which variations are mentioned, chromosome counts given so far as known, and additional references cited. All the known hybrids are listed, which will be particularly useful in *Asplenium* and *Dryopteris*, where many hybrids have been reported. There are a few errors, such as attributing the combination *Blechnum spicant* to Smith, although it was pointed out long ago that the proper authority is Roth, in Usteri, Neue Annalen 2(10): 46. 1794 (cf. Mansfeld in Repert. Sp. Nov. Fedde **45:** 202. 1938). The names *Equisetum maximum* Lam. and *E. limosum* L. are used, as often in the past, but both are incorrect, being properly *E. telmateia* Ehrh. and *E. fluviatile* L. The plant called *Pteris longifolia* in Europe is properly *P. vittata* L., as shown by Hieronymus (Hedwigia **54:** 290–294. 1914). The name *Lastrea* is adopted in the belief that *Thelypteris* is illegitimate, which may be true, but *Thelypteris* has been so widely used that it ought to be conserved, and has been proposed for conservation. *Gymnocarpium* is made a synonym of *Lastrea*, but this is hardly possible now. All the Thelypteridoideae, to which *Lastrea* belongs, are characterized by a peculiar type of one-celled acicular hair, always present at least on the costae above, but *Gymnocarpium* is glabrous like *Dryopteris* and has the same kind of capitate glands that *Dryopteris* sometimes has. The basic chromosome number is 41 like *Dryopteris*, whereas the Thelypteridoideae have lower numbers. Other characters ally *Gymnocarpium* with *Dryopteris;* therefore it belongs in the subfamily Dryopteridoideae and can not be a synonym of *Lastrea* in a different subfamily. An ultraconservative might include *Gymnocarpium* in *Dryopteris*, but the latter is more easily defined if it is excluded, for it has its own characters—thin, deciduous blades, veins reaching the margin, long, slender creeping rhizome with scattered fronds, generally scaleless condition, exindusiate sori, and a different facies, which is not to be ignored in deciding on generic boundaries. *Marsilea* is spelled "*Marsilia*," which may be a typographical error, but probably it is intended as a correction; perhaps "*Marsilia*" would have been a preferable spelling considering the name of the man which it honored, but Linnaeus chose *Marsilea* and it is not permissible to change his spelling now. In my copy of the Flora pages 129–144 are duplicated (which is preferable to having them omitted!). The name *Polystichum lobatum* is used rather than the correct *P. aculeatum*, which is rejected as a "nomen ambiguum"; since the species *aculeatum* can be and has been lectotypified it is really not ambiguous in its application in the future and its past ambiguity can not be eliminated by any known means. The comments on *Polypodium* are interesting. It is stated that *P. australe* of Shivas' treatment (diploid) can cross with American *P. virginianum* (diploid) and that there is full fertility; it is concluded then that the European diploid is really exactly *P. virginianum*, which is differentiated from the other European species by having some glandular paraphyses among the sporangia. The name *P. serratum* Willd. is adopted for the species named *P. interjectum* Shivas, but this can not be, for the name is a later homonym of *P. serratum* Aublet and therefore illegitimate. – C.V.M.

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Erratum

Page 65, last line: For "*multifora*" read "*multiflora.*"

Suggestions to Contributors

Manuscripts should follow recent Journal style and should be prepared in accordance with the second edition of the AIBS (1964) *Style Manual for Biological Journals.* For major articles with more than one literature reference, use the "name and year" system for bibliographic references and the American Standards Association list of bibliographic abbreviations (AIBS, 1964, pp. 74–87), which may be supplemented by the list of Schwarten and Rickett (1958). In other cases, put literature references in footnotes. Abbreviations of the names of herbaria should follow the list of Lanjouw and Stafleu (1964). Scales should be included on figures and plates, rather than indicating magnification in legends.

Manuscripts should have ample margins and should be typed double-spaced throughout, including the title, bibliography, and footnotes. Footnotes and tabular matter should be kept to a minimum. Reports of chromosome numbers will not be published unless documented by voucher specimens deposited in some herbarium.

Reprints should be ordered when galley proof is returned to the editor. An order blank will be included with the galley proof.

The payment or non-payment of page charges by authors' institutions or grants will affect neither the acceptability of manuscripts for publication nor the date of publication.

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